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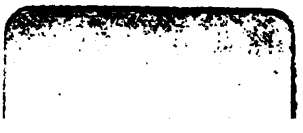

Harold W. Dorr.

Fifth Biennial Report

OF THE

Department of Engineering

OF THE

State of California

DECEMBER 1, 1914, TO NOVEMBER 30, 1916

CALIFORNIA STATE PRINTING OFFICE
SACRAMENTO
1917

Fifth Biennial Report

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Department of Engineering

OF THE

State of California

DECEMBER 1, 1914, TO NOVEMBER 30, 1916.

CALIFORNIA STATE PRINTING OFFICE
SACRAMENTO
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ANNOUNCEMENT

Early in 1916 the State Department of Engineering published Bulletin No. 2, Irrigation Districts in California, 1887–1915, by Frank Adams, Irrigation Manager, Office of Public Roads and Rural Engineering, United States Department of Agriculture. The little volume is a history of the irrigation district law, commonly known as the "Wright Law," and of the districts formed under it, compiled under cooperative agreement between the Federal and State governments.

The edition was quickly exhausted, and the receipt of several hundred applications for the bulletin which it was impossible to fill, caused the Department to decide to issue a second edition with which to supply the demand.

The reprint of Bulletin No. 2 will be found as Appendix B of this report.

one room in several instances. This statement is made [illegible] to indicate the size of the department as a state institution, and to emphasize the recommendations made herein.

1. The employees of the department are of two classes, statutory and nonstatutory. The first class are named by title and their compensation is fixed by the statute and paid from the general appropriation fund. The second class are those appointed by the department from time to time as their services may be required, and frequently are employed for special purposes. In this class are draftsmen, clerks, stenographers, inspectors, etc. Their compensation is charged against the institution or appropriation for the particular work in hand.

Several of these employees, such as the chief draftsman or the chief auditor, for instance, exercise supervision over many others, and it is extremely difficult to segregate their time equitably to the several appropriations.

It is recommended that the following appointments be added to the statutory list of employees:

Assistant State Architect.
Mechanical Engineer.
Structural Engineer.
Electrical Engineer.
Road Engineer.
Two Architectural Draftsmen at $175 per month, each.
Two Architectural Draftsmen at $150 per month, each.
Auditor.
Two Filing Clerks.
Two Clerks and Stenographers.
Blueprint Pressman.
Porter and Messenger.

2. In the article herein discussing irrigation districts it is pointed out that the statute requires the State Engineer to investigate the project of a proposed irrigation district and report upon its feasibility. The law only allows him one month to do it. Frequently there are no data at hand and the investigation must be in the nature of original research to ascertain the reliability of the water supply, the probable cost of dams and ditches, and the adaptability of the lands to irrigation. In many cases it is a physical impossibility to make an investigation in a month that will do justice to either the investigator or the project.

It is recommended that the State Engineer be given time to make the examinations in proportion to the magnitude of the enterprise and in no event should he be restricted to less than ninety days.

3. The Department of Engineering has no special fund from which to pay the costs of making investigations of proposed irrigation districts and the contingent fund provided is only sufficient to meet the regular demands made upon it. It is recommended that the contingent fund be made large enough to cover such investigations with the proviso that when a district shall be organized it reimburse the fund.

4. Before bonds can be issued by a district the plans for proposed work must be submitted to the State Engineer. He may approve the plans or recommend changes, and report his estimates of the cost. The district may accept his recommendations or ignore them entirely. This should not be. As consulting engineer his decision should be binding, and it is recommended that the law be amended so as to make it so.

5. The statute of 1913 provides that when works are being constructed from the proceeds of bonds the secretary of the district shall forward to the State Engineer copies of progress reports of construction. Some districts do not exact progress reports and have no copies to send. The same act (section 54½) provides that the State Engineer may cause to be made an examination of the affairs of any irrigation district and make such report thereon as he may deem advisable. Make report to whom? The statute does not say, nor does it confer authority upon anyone to act in case the examination should disclose that the work is not being done according to the plans, or that faulty works are being constructed and the funds wasted.

It is recommended that the act be so amended that the State Engineer's recommendations shall be binding and that a dereliction on the part of a district be reported to the Governor, who may direct proper proceedings.

6. There is no law now authorizing the consolidation of irrigation districts. Cases exist where two or more districts might be united under one management with benefit to both.

It is recommended that the law be amended to permit of consolidation of districts.

7. The present law authorizes the formation of an irrigation district composed of many tracts of land which may not necessarily be contiguous, but after a district is formed no other lands may be included or annexed unless they are contiguous to the district. Instances are known where desirable lands desire to be annexed, but being separated from the district by undesirable or hostile lands must be excluded.

It is recommended that desirable lands not contiguous to a district be enabled to enter the district.

8. No law exists authorizing an irrigation district to own property outside the state excepting the district embraces more than 500,000 acres. One district of 30,000 acres finds it is necessary to store its water in a reservoir situated just across the line in another state.

It is recommended that chapter 655, 1915, be amended so as to apply to all districts.

9. *In the matter of state supervision of dams.* The statutes of 1915, page 632, direct the Department of Engineering to pass upon all plans, specifications and estimates for the construction of dams. The department submits that to "pass upon" plans can be of little use unless changes in faulty plans can be prescribed and penalties enforced for departure from the approved plans. It is not claimed that the department should have police powers, but its findings should be submitted to some state authority having power to enforce police regulations.

It is recommended that it be made unlawful to erect a dam excepting the plans therefor be approved by the Department of Engineering, or to maintain a dam that is found defective or dangerous until measures satisfactory to the department have been taken to make it safe; the department be authorized to keep representatives present during construction or repairs affecting safety. Under the provisions of section 7, Statutes of 1909 (page 656), it is a felony for any member or employee of the department, or any contractor or his agent, to knowingly permit a violation of the provision of a contract on state work, or to have knowledge of such violation and not report it to the department. It is recommended that some such provision be made to apply to all constructions where a failure would endanger life and property.

10. Chapter 68, Statutes of 1881, requires plans of all bridges to be erected over navigable streams to be submitted to the State Engineer, who shall designate the width of draw and the length of spans necessary for the free passage of water. In the discussion herein of the subject, a case is cited of a railroad bridge over a nonnavigable stream which offered so much obstruction to the flood flow as to cause destruction of life and property.

It is recommended that it be made unlawful to erect a bridge over any stream which might cause damage without having the plans and location approved by the Department of Engineering.

11. Under hydroeconomics is discussed matters pertaining to flood control, and the desirability of having all flood control projects approved by the state. Whether a project be submitted to a State Reclamation Board, Flood Control Commission or other body, it is here contended that all engineering service required by the state in connection therewith should be executed by the Department of Engineering.

12. *In the matter of state roads.* The department now maintains more than six hundred miles of state roads in the high mountains, independently of the state highways. With the aid of the motor vehicle fund these roads have been much improved in the last two years, and their improved condition is evidenced by the greatly increased automobile travel over them. There is one of these roads, however, which this department considers of no use as a state road. Reference is had to the Sierra state road, in Sierra County. The projected length is twenty miles, of which fourteen miles were once surveyed and three miles built, extending from Downieville into the mountains. It does not connect any important communities, and would not be a part of any continuous system of state roads if completed. It is a liability and not an asset to the state.

It is recommended that the act creating it be repealed.

13. Attention is invited to the article on Water Resources, and particularly to the discussion of snow measurements in connection with stream measurements. Records of the quantity of water flowing in every important stream on every day of the year are being obtained. They are of immense value in the consideration of all problems of irrigation, navigation, flood control and reclamation.

If the knowledge obtained of the flow of streams was supplemented with a knowledge of the quantity of water held in reserve by the snows within the stream's drainage basin at any time, prediction could be made of the probable flood height to result therefrom, and preparations made accordingly.

When flood control reservoirs shall be built by knowing beforehand how much water is held in the snows, it will be known to a certainty how to manipulate the reservoir gates so as to impound the maximum quantity for irrigation and navigation, without impairing their usefulness for flood storage.

The appropriation for hydrographical work in cooperation with the United States Geological Survey is not sufficient to enable investigations to be made along the lines suggested.

It is therefore recommended that an appropriation of $10,000 be made to enable the department to make measurements and studies of snow storage, and that authority be given to enlist the cooperation of federal agencies and private concerns.

14. The importance of inland navigation is being felt very strongly now since the withdrawal of terminal rates from interior points. The department has given much thought to the subject, and presents a report thereon, the conclusions of which may be briefly summarized as follows:

It is engineeringly feasible to construct tidal canals capable of conveying ocean-going ships to Sacramento and Stockton, at a comparatively low cost.

It is engineeringly feasible to extend those canals several miles further into the interior, with locks.

Ships can be conveyed by canal within a few miles of San Jose.

It is no greater engineering problem to build a lock-canal for ships from the sea to the heart of the city of Los Angeles than it was to build the great Manchester Canal.

It would be no greater an engineering feat to build a barge canal from Red Bluff to Bakersfield than is the one now nearly accomplished of constructing the New York Barge Canal from Albany to Buffalo to accommodate barges carrying two thousand tons. The same distance and same elevations to overcome.

Investigations have not gone far enough to show what the costs of construction or of operation of such canals would be.

That all or any of the above are industrially feasible is not the province of this department to say, but it is urged that the question of cheap transportation is of such great importance to all that it should engage the earnest attention of the legislature to the end that an intensive study be made of the whole subject.

15. In the matter of certain employees of the department, it is desired to call attention to the fact that all maintenance work on state roads and all construction on river improvement is done by day labor. The jobs are short. The road work lasting from April or May to October, the river jobs seldom requiring more than two or three months each, though several may be running at once.

The majority of laborers employed upon these works are transient, and usually there are more applications for work than can be accepted, but an applicant not on the civil service list can not be given employment until that list is exhausted. Much time is lost in sending in requisitions from distant camps to the Civil Service Commission for men, frequently to find none or not enough on the waiting list to fill the requisition, and recourse must be had to temporary authority to employ nonlisted men.

Although the Civil Service Commission has always exerted every effort and given all assistance possible, the inevitable delays are annoying and frequently result in loss.

When the men are obtained, either from the Civil Service or otherwise, they generally will work only a short time. The average duration of employment of that class of labor is only about three weeks and the department fails to see where either the men or the service is benefited by their being under civil service regulations.

It is therefore urged that all transient labor of the department be exempted from the operation of the civil service.

The cordial relations sustained between the department and the various offices of the state government, the several institutions and the many branches of the federal government with which cooperative work has been conducted, has been a source of personal satisfaction and the State Engineer takes this opportunity of acknowledging the many courtesies received at the hands of all with whom dealings have been had.

PART I.

Fifth Biennial Report of the Department of Engineering of the State of California.

The Department of Engineering was created by an act of the legislature approved March 11, 1907, chapter 183, Statutes 1907, and was organized in the May following.

The act creating this department abolished the offices of Commissioner of Public Works, Auditing Board to the Commissioner of Public Works, Department of Highways and State Highway Commissioner, Lake Tahoe Wagon Road Commissioner, and Debris Commissioner, and delegated the performance of their several duties to the Department of Engineering. To the department was also assigned all engineering work for the Board of Harbor Commissioners of San Francisco and the design and construction of buildings and works for all the hospitals, prisons, schools, and other state institutions. It was given authority to cooperate with the Department of the Interior and other departments and bureaus of the national government in making surveys, investigations, etc.

Mr. Nathaniel Ellery was appointed to the position of State Engineer and chief executive officer of the Department of Engineering, and assumed the office May 11, 1907. He was succeeded in office by the appointment of Mr. Wilbur F. McClure, incumbent, February 13, 1912.

The records of the organization of the department and the work accomplished by it from the date of its establishment to November 30, 1914, have been published in the reports issued every two years, and it is the office of this report to review the operations of the department during the biennial period just closing.

Since the department was created, each session of the legislature has enacted laws amending the statutes affecting the work of the department, the most notable of which was to enable it to handle the administration of the State Highways Act, which provided for the construction of an extensive system of state highways. Many of the statutes have added greatly to the functions of the department.

DEPARTMENT OF ENGINEERING.

Under the statutes now in force the Department of Engineering is composed of three bodies: Advisory Board, Consulting Board, and Executive Force. These three bodies are constituted respectively as follows:

THE ADVISORY BOARD.

Governor, ex officio member and chairman.

General Superintendent of State Hospitals, ex officio member.

Chairman of Board of State Harbor Commissioners of San Francisco, ex officio member.

State Engineer, appointed by the Governor, ex officio member.

Three members, appointed by the Governor.

The Advisory Board is the administrative head, and directs the operations of the department through the State Engineer, who is the chief executive officer of the department.

The ex officio members receive no salary as members of the Advisory Board. The three last-named appointed members of the Advisory Board are delegated as a special executive committee of the board to administer the affairs of the state highway bond projects, and bear the title of State Highway Commission. These members are paid salaries.

THE CONSULTING BOARD.

This board is composed of five members appointed by the Governor and serve without compensation. The functions of this board are to act as intermediary between the people desiring public work done on the rivers and the Department of Engineering; receive and consider petitions and make recommendations to the department in regard to proposed work pertaining to drainage, irrigation, and river improvement. This board holds meetings at the call of the State Engineer.

EXECUTIVE FORCE.

State Engineer, Chief Executive Officer.
Two Assistant State Engineers.
State Highway Engineer.
Chief Harbor Engineer.
State Architect.
Architectural Designer.
Secretary.

The foregoing comprises all of the "statutory" employees whose positions were created by statute, and whose salaries are paid from the fund created by the "General Appropriation Act."

The field of operations conducted by the Department of Engineering has grown with such rapidity and to such dimensions that it has been found necessary to create new offices and to employ a much larger force than was contemplated when the department was created.

The universal employment of electricity for lighting, power, communication, and in the hospitals its extensive use in therapy, requires a large force of electricians, and to properly direct their work, the employment of an electrical engineer is necessary.

A vast amount of construction and repair of state property is done directly by the Department of Engineering, entailing the purchase of immense quantities of materials, machinery and apparatus.

To effect economy in this line a purchasing office was necessary, which was maintained under the direction of a [1]Purchasing Agent.

The construction of buildings along modern lines and on the large scale conducted by this department requires the use of immense quantities of cement, stone, bricks, metals, asphalts, oils, paints and all the materials entering into the construction and furnishing of public buildings. To insure that each article should conform to the specifications a testing laboratory was early established and has been constantly employed under charge of a [2]Testing Engineer.

The rapid growth of automobile traffic in the mountains with its insistent demands for a higher grade of road maintenance necessitated the creation of the office of Road Engineer to properly direct the work on the hundreds of miles of state roads traversing the scenic regions of the high Sierras.

The increasing demands for improvement of the navigable rivers of the state entailing continuous effort in bank protection and channel rectification, gives constant employment to a large force under the direction of a river superintendent.

The expenditure of several millions of dollars entrusted to the department requires a considerable force of accountants, directed by an auditor, in whose keeping is also placed the records and archives of the department.

In addition to those enumerated above, the department constantly requires the services of draftsmen, architectural and structural engineers, surveyors and their crews, superintendents, inspectors, and men in many other capacities, down to cooks, waiters, and roustabouts in the road and river construction camps.

The foregoing constitutes the "nonstatutory force." The compensation of these employees is paid usually from the funds appropriated for the construction upon which they are employed. Frequently this can not be done, and then the employee is paid from the department's "contingent fund."

So many of the nonstatutory positions are permanent in character, and as the incumbents are civil service employees, it is believed better

[1]The duties of this office were taken over by the State Purchasing Department on September 15, 1916.

[2]The office of Testing Engineer was transferred to the State Purchasing Department in July 1, 1916.

service will result from extending the list of statutory offices. This is a matter that is earnestly commended to the consideration of the coming legislature.

DUTIES OF THE DEPARTMENT.

The above list of employments indicates to some extent the varied nature of the department's activities and the extent of the field covered by it. Its duties, as specified by several statutes, are summarized as follows:

To make plans and specifications for all buildings at the various state institutions, to let contracts for and superintend their erection, or, in case satisfactory contracts can not be made, to construct the buildings by day labor. To design and install all heating, lighting, ventilating, refrigerating, water supply, sewerage, and mechanical plants of every nature—whether changes, extensions or original. Survey grounds, lay out walks, drives and roads; provide water supply, irrigation, reclamation, sewer and drainage systems, requiring the design and construction of dams, reservoirs, pipe lines, wells, pumping plants, ditches, sewage treatment and disposal plants and drains.

Design and construct works for the protection of river levees, preservation of navigation and protection from floods.

Conduct research looking to the reclamation of the overflow basins and to effect flood control on the Sacramento and San Joaquin and other rivers of the state.

Studies of the feasibility of navigable canals and canalization of rivers.

Through the engineering force assigned to the Board of Harbor Commissioners, to design and direct the construction of wharves, piers, buildings and their equipment on the water front of San Francisco.

Location, construction, repair and maintenance of state roads, of which there are more than 600 miles in the mountain regions.

Through the Highway Commission, the location and construction is being conducted of the system of highways authorized by the state highway bond acts.

The administration of the Motor Vehicle Act, involving the issue and registry of all licenses for motor vehicles. The issuance of licenses for the operation of motor vehicles was placed in the Department of Engineering by an act approved May 31, 1913. To handle the matters pertaining to this required the erection of a division especially for that purpose, which continued as a part of this department until the creation of a separate Motor Vehicle Department in 1915.

By cooperation with the federal government a topographic survey of the state is being made; daily measurements are made of the water flowing in all the principal and many of the minor streams of the state; studies of possibilities for developments of power in the mountains and irrigation in the plains. Investigation of the quantity of water required

for various crops; methods of applying it, waste in the use of water, etc.

This department is required to cooperate with the engineers of the War Department in matters concerning debris control, flood control and aids to navigation.

The State Engineer is required to investigate and pass upon the feasibility of the enterprise before an irrigation district can be organized, and must approve the estimates for a projected bond issue. He is a member of the Irrigation District Bond Commission and is required upon application, to investigate the engineering features of the projects of irrigation and county water works districts, where the latter desire to have their bonds accepted as state securities, and thereafter he supervises the construction of works executed with proceeds of validated bonds.

He is ex officio a member of the State Water Commission, which body has control of all water appropriations and the ascertainment of water rights. He is also a member of the Carey Act Land Board.

The State Engineer is required by law to direct the engineering investigations for the Reclamation Board to determine the proper location and sufficiency of proposed reclamation works, so that they shall conform to the plan for the flood control adopted by the state.

Plans for all bridges to cross navigable streams are required to be approved by the State Engineer before they are permitted to be erected.

The law directs that he shall pass upon the plans, specifications and estimates of all dams constructed in the state.

In addition to the active duties enumerated above, the department conducts an extensive correspondence, answering queries from all over the country seeking information in regard to the extent of drainage, reclamation, irrigation and power developments, and many other lines of progress in the state, and the costs thereof. If the information is at hand or can be obtained it is always furnished. This is done upon the theory that all public offices should be in a measure publicity bureaus, and the dissemination of correct information as to the resources of the state and its advantages is a proper function of all branches of the government.

The department has been called upon by municipalities for advice in regard to sewage disposal; by communities asking for the examination of dams, as to their stability and safety, and specifications to strengthen the same, as well as advice regarding flood protection and stream control in different portions of the state. While these are not duties enjoined by law upon the department, the State Engineer has always responded to such requests and given such assistance in an advisory way as the department was able to furnish, and it is gratifying to know that such aid has been regarded of value by the recipients.

ORGANIZATION.

As previously stated, the department is divided into branches to handle each different kind of work. These branches are termed bureaus. The executive head of each bureau is called the director. He reports directly to the State Engineer.

The bureaus as now established are as follows:

I. General Office Bureau.
II. Bureau of Architecture.
III. Bureau of Economics.
IV. Bureau of Highways.

I. The General Office Bureau conducts the business of the department relating to all other branches, such as keeping the records and archives, accounts, contracts, claims and payments, legislation, janitor and messenger service, etc.

II. The Bureau of Architecture, as its name implies, designs and constructs all state buildings.

III. The Bureau of Economics has charge of all matters pertaining to hydraulics, such as irrigation, stream measurement, flood control, reclamation, drainage, and navigation.

Plans for water supply, for sewerage, irrigation, drainage and reclamation, roads and bridges, topographic surveys of grounds and surveys of land boundaries for all state institutions are entrusted to this bureau.

Supervision of dams and bridges is exercised through this bureau.

This bureau also has charge for the state of cooperative topographic surveys, hydrology and irrigation investigations.

The office of State Roads is also in this bureau. By this is meant the roads owned by the state in the mountain regions as distinguished from the state highways under the Highway Commission.

IV. That branch of the department designated herein as Bureau of Highways was created for the purpose of carrying out the Highway Bond Acts. It has such a huge task, requiring so complete an organization for one specific purpose that it almost constitutes a separate department. It is, however, a part of the Department of Engineering and is administered through the direction of members of the Advisory Board delegated to that duty.

PERSONNEL.

At the date of this writing, November 1, 1916, the Department of Engineering is organized as follows:

ADVISORY BOARD.

Hiram W. Johnson.....Governor (Chairman)
W. F. McClure.....State Engineer
J. J. Dwyer.....President State Board of Harbor Commissioners
F. W. Hatch.....General Superintendent of State Hospitals
Charles D. Blaney (Chairman), N. D. Darlington, Charles F. Stern...State Highway Commission

CONSULTING BOARD.

Alexander Gordon.....Chairman

G. W. Tatterson, Stockton.	M. J. Boggs, Colusa.
W. J. Smith, Grand Island.	E. S. Brown, Sacramento.

EXECUTIVE OFFICE.

Title	Name	Entered service
State Engineer	W. F. McClure	Feb. 12, 1912
Secretary	Earle Freeman	Mar. 13, 1912

GENERAL OFFICE BUREAU.

Secretary.....Director

Title	Name	Entered service
Division of Correspondence—		
Stenographer	Lucy K. Adams	April 1, 1912
Stenographer	Henrietta Burt	May 16, 1913
Messenger	Wesley J. Ketcham	July 21, 1915
Division of Accounts—		
Auditor	J. H. Clarke	Nov. 11, 1911
Filing Clerk	Chas. Johnston	July 8, 1907
Filing Clerk	J. C. McCalmont	Mar. 26, 1912
Clerk	A. J. Adams	May 28, 1909
Clerk	H. B. Glover	May 16, 1916
Clerk	Thos. McCully	Feb. 1, 1916
Clerk	F. M. Stewart	July 28, 1916
Clerk	N. E. White	April 15, 1912
Stenographer	M. A. Ahern	June 1, 1916
Stenographer	G. H. Hermansen	Aug. 4, 1916

BUREAU OF ARCHITECTURE.

State Architect.....Director
Assistant State Architect.....Superintendent

Title	Name	Entered service
Director's Office—		
State Architect	George B. McDougall	Aug. 22, 1913
Assistant State Architect	Jas. S. Dean	Aug. 1, 1912
Stenographer	Grace E. DuFour	Aug. 1, 1912
Stenographer	Elsa Koch	Mar. 25, 1914
Stenographer	Gladys McMillan	Aug. 3, 1916
Clerk	Harold McMillan	Oct. 1, 1914
Blue Printer	Frank Butler	April 1, 1912
Architectural Division—		
Assistant State Architect.....Chief		
Chief Architectural Designer	Chas. F. Dean	Sept. 23, 1911
Architectural Designer	R. E. Backus	Sept. 1, 1912
Architectural Designer	A. R. Widdowson	July 17, 1911
Specification Writer	W. C. Hough	Aug. 11, 1913
Estimator	I. C. Satterlee	July 17, 1914
Draftsman	Geo. J. Adams	Aug. 16, 1915
Draftsman	W. E. Baumberger	Aug. 24, 1914
Draftsman	P. W. DeLongchamps	Aug. 11, 1913
Draftsman	J. G. Heath	Feb. 1, 1913
Draftsman	H. F. Horn	Aug. 25, 1913
Draftsman	Walter J. Long	Nov. 12, 1912
Draftsman	Carleton Pierson	Jan. 20, 1913
Draftsman	Leroy F. Sherwood	Jan. 1, 1913
Engineering Division—		
General Superintendent.....Chief		
General Superintendent		
Structural Engineer	Clarence H. Kromer	Feb. 16, 1913
Mechanical Engineer	L. B. Luppen	Aug. 1, 1912
Mechanical Draftsman	A. J. Zschokke	Jan. 7, 1914

BUREAU OF ARCHITECTURE—Continued.

Title	Name	Entered service
Engineering Division—Continued.		
Mechanical Draftsman	J. B. Hawley	July 12, 1915
Mechanical Draftsman	C. A. Henderlong	April 28, 1914
Mechanical Draftsman	E. H. Hogan	Mar. 4, 1914
Mechanical Draftsman	L. E. Rushton	July 6, 1915
Mechanical Draftsman	P. H. Steiner	Oct. 19, 1914
Mechanical Draftsman	C. G. Zschockelt	June 30, 1915
Electrical Engineer	G. D. Jones	----------
Electrical Draftsman	G. M. Simonson	Sept. 22, 1913

BUREAU OF ECONOMICS.

Assistant State Engineer.....Director

Title	Name	Entered service
Assistant State Engineer	Paul M. Norboe	May 17, 1907
Flood Control and Reclamation Division—		
Assistant State Engineer.....Chief		
Flood Control Engineer[1]	E. A. Bailey	June 1, 1912
Navigation Division—		
Assistant State Engineer.....Chief		
Chief Engineer, San Francisco Harbor[2]	Frank G. White	July 7, 1916
Hydrographer	J. B. Brown	June 26, 1913
Superintendent of River Work	W. W. Wooldridge	Jan. 1, 1908
Foreman, river work	Frank E. Wooldridge	Sept. 1, 1909
Foreman, river work	Clifford Childers	May 15, 1912
Clerk	Thomas Sweeney	April 20, 1914
Boat Engineer	Orland W. Wallace	May 15, 1912
Cook	Hom Wo[3]	Nov. 2, 1914
Irrigation Division—		
Assistant State Engineer.....Chief		
Project Examiner	W. L. Huber[4]	Occasional.
Division of Cooperative Research—		
Assistant State Engineer.....Chief		
U. S. Geological Survey—		
Topographic	George A. Davis	----------
Hydrographic	H. D. McGlashan	----------
U. S. Department of Agriculture—		
Irrigation Inquiry	Frank Adams	----------
Division of Institutional Service—		
Assistant State Engineer.....Chief		
Engineer	E. D. Nickerson	April 18, 1914
State Road Division—		
Assistant State Engineer.....Chief		
Road Engineer	H. H. Blee	April 10, 1913
Location Engineer	R. F. Williams[5]	Feb. 15, 1912
Road Superintendent	E. M. Baxter	June 1, 1910
Road Superintendent	H. L. Leventon	Sept. 16, 1915
Road Superintendent	Grant P. Merrill	Aug. 15, 1912
Road Superintendent	L. H. Cook	Oct. —, 1912
Road Superintendent	H. E. Wood	May 21, 1915
Road Superintendent	F. W. Matthews	July 15, 1911
Road Superintendent	W. H. Stone	June 29, 1915
Road Superintendent	Chas. M. Stewart	Dec. 30, 1911
Road Superintendent	L. C. Chase	June 1, 1913
Road Superintendent	W. H. Dool	Oct. 1, 1914
Road Superintendent	E. E. Newell	June 7, 1915
Road Superintendent	J. E. Mitchell	May 13, 1912
Road Superintendent	W. J. C. Dinsmore	May 23, 1913

[1]Assigned to duty with State Reclamation Board.
[2]Appointed Chief Engineer, San Francisco Harbor Commission, succeeding Jerome K. Newman, July 1, 1916.
[3]Native American of Chinese parentage.
[4]Occasionally employed for special occasions.
[5]Transferred from Highway Commission Division, June 6, 1916.

The Bureau of State Highways, under the directorship of the Highway Commission with Mr. A. B. Fletcher, Highway Engineer, has such an extensive list of employees, and inasmuch as the commission will submit separate report of its work, the personnel is omitted here.

In addition to the employees enumerated above, which constitutes a permanent force required for the orderly conduct of the various duties devolving upon the Department of Engineering, there is a large number of semipermanent and temporary employments such as road engineers, foremen and laborers, teamsters, cooks, etc., employed on mountain roads during the summer; foremen, laborers, cooks, etc., employed from time to time on river work; draughtsmen, tracers, computers, inspectors, etc., required in the architectural division during rushes of work, and extra clerks and stenographers in the several divisions at times when work accumulates.

STATE INSTITUTIONS.

The state institutions for which the services of the Department of Engineering are required under the law, are as follows:

Educational.

Chico State Normal School.
Fresno State Normal School.
Humboldt State Normal School, Arcata.
Los Angeles State Normal School.
San Diego State Normal School.
San Francisco State Normal School.
San Jose State Normal School.
Santa Barbara State Normal School of Manual Arts and Home Economics.
San Luis Obispo State Polytechnic School.

Eleemosynary.

California School for the Deaf and the Blind, Berkeley.
Industrial Home of Mechanical Trades for Adult Blind, Oakland.

State Hospitals.

Agnews, Agnew, Santa Clara County.
Mendocino, Ukiah, Mendocino County.
Napa, Napa, Napa County.
Norwalk, Norwalk, Los Angeles County.
Southern California, Patton, San Bernardino County.
Stockton, Stockton, San Joaquin County.
Sonoma State Home (for feeble-minded children), Eldridge, Sonoma County.

Punitive.

State Prison, Represa, Sacramento County.
State Prison, San Quentin, Marin County.

Reformatory.

Preston School of Industry, Ione, Amador County.
Whittier State School, Whittier, Los Angeles County.
California State School for Girls, Ventura, Ventura County.

Military.

Veterans' Home, Yountville, Napa County.
State Arsenal and Armory, Sacramento.
State Armory, San Francisco.
State Armory, Los Angeles.
State Armory, Stockton.

Miscellaneous.

State Capitol, building and grounds, Sacramento.
Governor's Mansion, Sacramento.
State Printing Office, Sacramento.
State Fair, buildings and grounds, Sacramento.
Sutter's Fort, buildings and grounds, Sacramento.

PLATE I.

Mission Solano, Sonoma, restored.

Old Greek Church at Fort Ross, restored.

Harbor Front, wharves, piers and buildings, San Francisco.
Mission Solano, Sonoma County (restoration).
Old Russian Church, Fort Ross (restoration).
State Fish and Game Commission, Hatcheries.
Los Angeles Exposition Building.
State Office Buildings, Sacramento (authorized, not commenced).
State Office Buildings, San Francisco (authorized, not commenced).

Architectural service at state institutions.

All work of the department pertaining to state buildings, whether relating to the preparation of plans and specifications, or erection and installation, including mechanical plants of every kind, is executed by the architectural bureau of the department, and a review of the work accomplished by that bureau will be found under the report of the State Architect.

Engineering service at state institutions.

Whenever improvements are contemplated at an institution, whether it be a new building, or whether water pipes, sewers, walks or drives are to be extended, the first thing needed is a topographic map, showing the location of existing buildings and all the natural and artificial topographic features of the grounds. To meet this demand the department has from time to time executed surveys at several institutions and constructed maps thereof, so that now the department possesses such maps of many of the state institutions. Lack of funds, however, has prevented the prosecution of these surveys for all institutions. The absence of data furnished by such maps is keenly felt whenever the architects are called upon to design a new building, as its location and surroundings control or, at least, suggest the type of architectural appearance to be given to the building. The engineers who design the heating, water supply and sewage are greatly aided in their studies by accurate maps. The proper location of roads, drives and walks, and the arranging of scenic effects by the landscape artists are also better done when access is had to such data.

It is hoped that the department will soon be able to make such maps of all institutions not yet surveyed, and to bring those already made up to date.

Agnews State Hospital.

Sewerage. Excepting for breaks in the outfall sewer from washouts caused primarily by the work of a dredge, there has been little trouble with the sewer system. These breaks were repaired upon the advice of the department by the employees of the hospital.

The disposal of sewage here is by discharge into San Francisco Bay. Many of the towns and cities situated around the bay discharge their raw sewage into the head of the bay. Although the waters are subject to daily tides, the sewage is not carried out to sea, but remains to

decompose in a comparatively small area. The offense from this will in a few years become unbearable, and the discharge of raw sewage into the bay will be prevented.

This is a matter that should be given thought at the State Hospital and plans prepared for a treatment plant that will render its wastes inoffensive.

Land Drainage. In previous reports it has been pointed out that a large part of the hospital's lands could be made more productive by drainage. A plan has been partially worked out, but nothing has ever been done to carry it into effect. The matter is again commended for consideration.

Mendocino State Hospital.

Water Supply. The dam and reservoir provided for in two appropriations, 1911 and 1913, of $12,500 each, has been completed. The dam is 63 feet high and the reservoir has a capacity of about 45,000,000 gallons. This, with the 8,000,000 gallons of the old reservoir, should give the institution ample water for a long time.

The construction of this dam proved to be much more difficult than had been anticipated. What appeared on the surface to be a rock ledge proved to be badly shattered underneath, and it was necessary to carry the concrete of the dam nearly a hundred feet into the rocky mass.

Even at this distance the formation was not satisfactory, and it was believed that a water-tight contact could not be effected. It was thought, however, that any leakage around the dam through the country rock would not become dangerous to the structure. Its completion and the filling of the reservoir proved the correctness of the theory, as when the water had reached a depth of 50 feet on the dam, leakage around it, which appeared in the creek bed below, developed to quite a considerable quantity.

This leakage is all intercepted by the lower dam, and so long as it does not exceed in quantity the capacity of the pipe lines conveying the water to the hospital, no loss will occur.

It is not seen now how the leaks can be stopped excepting at great cost, but as no danger is apparent it is not believed action of any kind is required.

Repairs to lower dam. This dam, 27 feet high, was constructed several years ago, before the state had a department to design such works. The section is so thin that only the very best of materials and workmanship could have preserved it. A slight vertical crack developed in the masonry over the outlet, and as no suitable foundation could be found for buttresses, a rock fill was placed against the downstream face of the dam. To prevent the fill being washed away by floods, the dam being of

PLATE II.

Top—Female Nurses' Home, Agnews State Hospital.
Middle—Superintendent's Residence, Southern California State Hospital.
Bottom—Chamber's Cottage, Napa State Hospital.

PLATE III.

Women's Building, State Fair.

Entrance, Women's Building, State Fair.

the overflow type, a wasteway was cut in the crest of the dam and a concrete chute built down the slope of the fill, terminating in an upturned apron at the lower end to deflect the water upward and beyond the footings, where it falls upon a ledge of rock, avoiding all scour.

Pipe Line. An appropriation of $15,000 was made by chapter 192, 1915, to replace the old pipe line which became so badly corroded as to be frequently breaking and threatened complete failure. The new pipe was laid and completed under the direction of the department, superintendence and inspection was furnished by the hospital, Mr. N. S. Burge, general manager, being in charge. The unskilled labor was mostly performed by patients.

Napa State Hospital.

Water Supply. The water for domestic use and irrigation is obtained from three sources, viz: a storage reservoir in a canyon above the institution, from Spencer Creek and from wells on the grounds.

The dam making the reservoir, which is called by the people at the hospital Lake Marie, was constructed several years ago. It was under construction at the time the Department of Engineering was created, and was completed under the direction of the department.

It is an earth and rock fill, having a concrete core wall and rock riprap on the water slope. An ample wasteway is provided by a cut through rock at one end of the dam.

In the spring of 1916 a leak developed which caused the management of the hospital considerable alarm. An engineer from the department visited the dam, and while he did not find that any immediate danger threatened, under his direction the water was lowered in the reservoir. When the surface had fallen about four feet the leak ceased, indicating that the cause existed somewhere within four feet of the height of the wasteway. The inflow from the creek had ceased, so it was not possible to raise the surface of the water and start the leak again, so as to form a "lead" to trace to its origin. It is intended that when the reservoir shall fill again, explorations shall be made to ascertain the cause and apply remedies.

Withdrawing water as above stated depleted the supply to such an extent that the institution was threatened during the summer with a serious shortage. The supply from Spencer Creek had practically ceased. One of the two good wells at the institution was lost two years ago by accidentally dropping a heavy pump into it, which resisted all effort to remove.

An old unused well in the boiler room was cleaned out, relined with new casing and put into service. This, with the old well already in use, furnished about 120,000 gallons a day when being pumped continuously. Early in October the management engaged a well-driller

to drill another well on the grounds, but at the date of this writing it is not completed. It is not anticipated that these wells will furnish more water than is required with the most rigid economy, unless copious rains shall soon occur to fill the reservoir.

The experience of this season, with the certainty that the quantity of water needed for the institution will be greater every year, demonstrates the imperative need for measures to be at once adopted to secure a sufficient supply from another source.

It has been suggested that another dam might be constructed in the canyon about a mile below Lake Marie.

In the absence of data as to run-off and without thorough exploration of the proposed reservoir site this department feels grave doubt that a reservoir of sufficient capacity can be filled, or if filled, that it would hold the water impounded. This doubt is due to the knowledge of the very limited area of watershed tributary to the site, and to the broken character of the rock forming the floor of the reservoir.

It is believed that a careful reconnaisance of the hills and canyons for several miles around might disclose an ample supply of water for Napa State Hospital, as well as, possibly, some other near-by state institution.

The Tide Land Reclamation. The reclamation of 380 acres of tide lands along the Napa River, as related in the last report, has proved very effective and has added a large area to the productive farming lands of the hospital. The tract is in need of a drainage system, the operation of which will extend the cropping season in the lowest portions several months. The department is considering plans for such system.

Stockton State Hospital.

Farm Drainage. In former reports it has been stated that the hospital farm some two or three miles from the institution is subject to inundation. That danger is now fairly well protected against, but the surface drainage from the higher lands of the farm accumulates in the low lands, and being augmented by seepage from the water against the outside of the levees, renders the lowest portions unproductive. Estimates have been furnished to the institution showing that a pumping plant to clear the land will cost about $7,000.

Sonoma State Home.

Water Supply. The water for domestic use at this institution is obtained from several springs in the wooded ravines of the hills in the western portion of the estate. The water, which is of most excellent quality, is conveyed in iron pipes to two concrete tanks of about 1,000,000 gallons capacity each, situated on a hill about 150 feet in elevation above the grounds of the home. From these tanks it is distributed to the buildings and grounds. For many years this source

PLATE IV.

Top—Typical Cottage, State School for Girls, Ventura.
Middle—Typical Cottage, State School for Girls, Ventura.
Bottom—Detention Building, State School for Girls, Ventura.

(p. 24)

furnished sufficient water for domestic purposes and also for irrigating the lawns, but with an increase in population the supply became inadequate.

In 1910 the department constructed an earthen dam across the lower end of a small valley in the hills about a mile back of the home, creating a reservoir with a capacity of about seventy-five acre feet. A pipe line to the institution enables this water to be used for irrigation about the grounds; to supply fire hydrants, and also furnishes water for flushing purposes in some of the buildings. The quality of the water, however, renders it unfit for domestic use, and it is excluded from the domestic pipes.

A gas engine in the creek which traverses the estate pumps water through a pipe line to the dairy farm, where it is used for irrigating garden truck.

The domestic supply is not fully up to the requirements of the home. In the summer when the flow from the springs reaches the minimum, much apprehension is felt that a shortage will ensue, and with the accession of population which will follow the completion of accommodations for them now under construction or contemplated, the supply will surely be insufficient. Some saving can be made in the use of water by improving the plumbing of some buildings, but undoubtedly an increase of population will create demands that can not be met from the present source.

The new buildings now being erected will also need a supply of irrigation water to improve its grounds. This can not be had from the present system.

An appropriation of $10,000 was made (chapter 433, Statutes 1913) for improving the water supply. An attempt was made by drilling wells, but failed to find a supply.

The geologic formation of the country in the near vicinity of the home does not give encouragement that a source of supply of potable water sufficient for the institution can be found within a reasonable distance.

The department is now working upon a plan to install a pumping plant to take water from the bed of Sonoma Creek, and use that for all purposes that do not require pure water, and to install a plant to sterilize and filter that required for domestic use.

Sewerage. The hydrolytic tank under construction at the time of the last report has been completed and installed with a chemical plant for treating the effluent. It has given satisfactory service since its installation, but has not been in operation long enough to determine the best method of manipulation under the changing conditions of continuous use.

The boys' barracks being constructed on the grounds is located away from the system of sewer pipes, and will require an independent line to reach the hydrolytic plant. No funds are now available for that purpose.

Roads. During the present biennium the road to the fields in the hills has been changed in alignment, substituting a grade of 8 per cent maximum for the former dangerous grades. The funds were not sufficient for surfacing all of it, but it is probable that the surfacing may be accomplished a little at a time by the institution.

There is need, though, of an appropriation to extend road building into the remote hayfields.

State Fair Grounds.

An act approved June 6, 1913, appropriated $10,000 to be used for the disposal of drainage and sewage from the State Fair grounds at Agricultural Park, Sacramento.

Owing to the absence of any sewers or means of public disposal of sewage in the portion of the city where the fair grounds are situated, sanitary conditions were extremely bad, and growing worse at each recurrence of the State Fair. There being no means of effecting proper disposal of the sewage, temporary expedients were resorted to each year until 1916.

The city's new sewer system was extended to the vicinity of the fair grounds, the local system was connected up in time to be of service to the National Guard Mobilization Camp, which preceded the State Fair a few weeks.

For the purpose of connecting the system with the city's sewers, new lines were laid throughout the grounds as well as connecting several wash racks at the barns and stock pens.

The State Fair now has a complete and serviceable sewer system so laid that all new buildings erected in the future may be easily connected therewith.

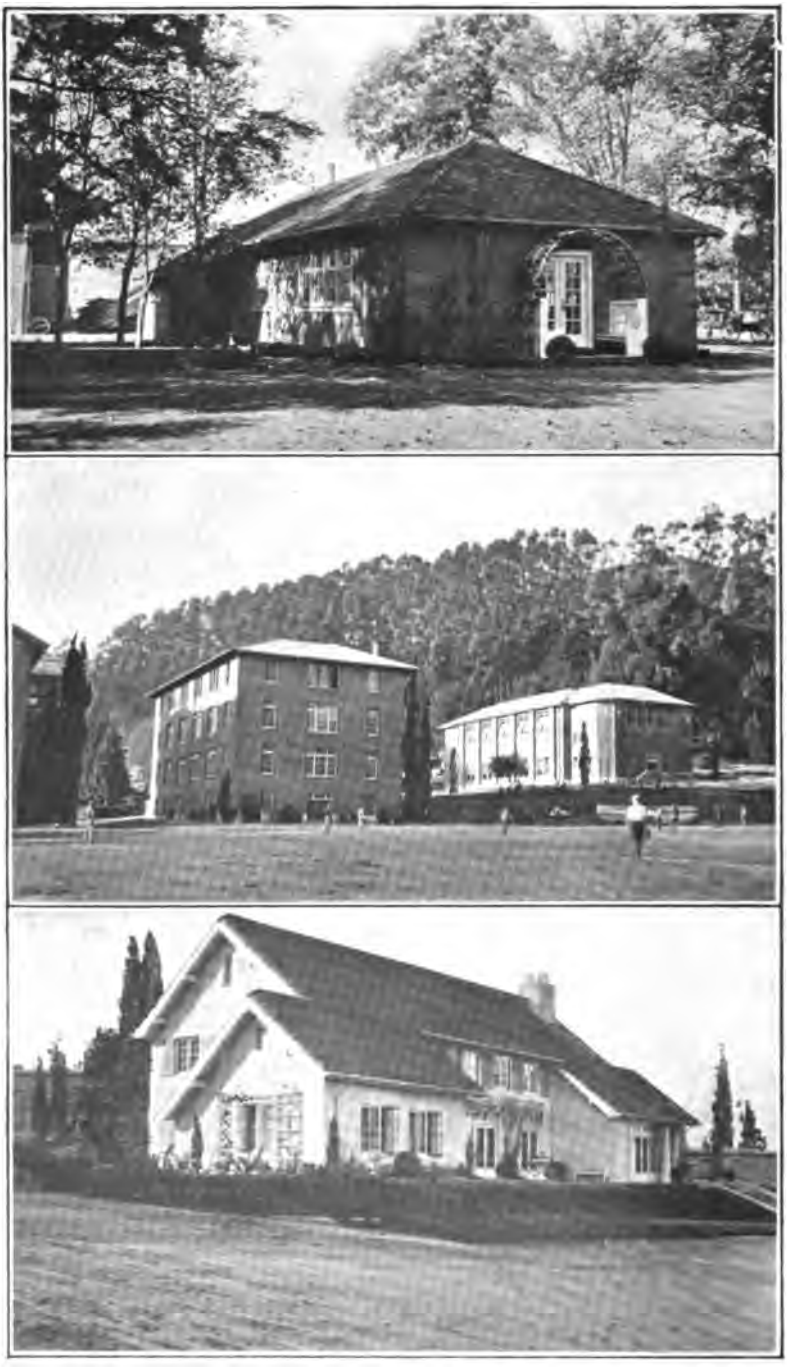
BUREAU OF ARCHITECTURE REPORT COVERING OPERATIONS FROM NOVEMBER 1, 1914 TO OCTOBER 31, 1916.

By GEORGE B. MCDOUGALL, State Architect.

The Bureau of Architecture of the Department of Engineering has charge of all work of the Department of Engineering: First, at 23 different state institutions, which have a combined population in students, patients and prisoners of about 20,000; and second, at 17 other state institutions or enterprises, making a total of 40 different institutions and enterprises.

During the biennial period just ended the bureau has been housed on the sixth floor of the Forum building, under conditions which have been satisfactory and favorable to the production of the best results.

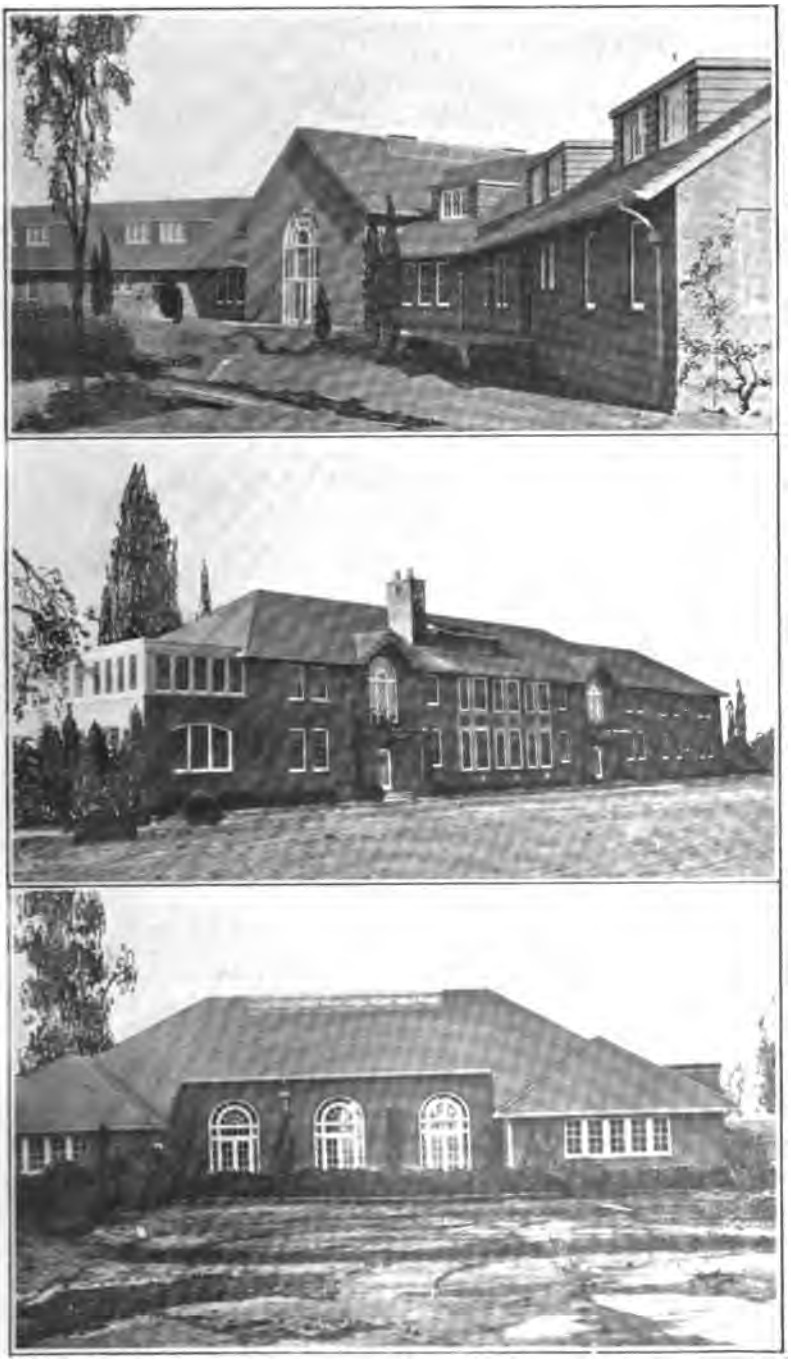
PLATE V.



Top—Cafeteria, San Jose State Normal School.
Middle—Gymnasium, School for Deaf and Blind, Berkeley.
Bottom—Warden's Residence, State Prison, Represa.

(p. 26)

PLATE VI.



Top—Kitchen and Commissary, Norwalk State Hospital.
Middle—Workers' Cottage, Norwalk State Hospital.
Bottom—Power House, Norwalk State Hospital.

(p. 26)

There were authorized by the legislature of 1915, 81 special appropriations, aggregating $1,148,365.08, for building construction distributed amongst these 40 different institutions and enterprises and, in addition to this, estimates from the several boards of management have been approved during the past two years for 43 different pieces of construction, similarly distributed, aggregating in cost $216,055.26. This, added to the amount of the appropriations, makes a total of $1,364,420.34 for 124 different pieces of work.

There is necessarily a considerable amount of office work done in connection with proposed construction at these various institutions that is never carried through and is not taken into account in the above figures. In addition to this, it is impossible for us to deny requests for counsel and advice from the various institutions, and the aggregate amount of time given during a biennial period to consultation, making of sketches and general assistance, is very considerable.

Of these 124 pieces of work referred to above, 14 were of a value less than $1,000; 75 were between $1,000 and $12,500; 13 were between $12,500 and $20,000; 19 were between $20,000 and $50,000, and three were over $50,000.

The extremely large proportion of work of small cost as indicated by the figures just given, together with work in connection with proposed construction never erected and the large amount of time consumed in advisory consultation, already referred to, make the average percentage of cost for our office work higher than would be the case otherwise.

For the purpose of indicating in detail the cost of our work, a list of 29 items, fairly representing the total of 124, is given at the end of this report. The total cost of these 29 pieces of construction as shown by our books is $466,209; the expense for our office work, $23,790.57, or 5.10 per cent of the total, and the expense for inspection $9,801.72, or 2.1 per cent of the total. These constructions are entirely completed.

In the biennial report for the period which ended October 31, 1914, it was shown that the cost percentages corresponding with those given above were 4½ per cent and ¾ per cent; this indicates increases for the period ended October 31, 1916, of ⅝ per cent for the office work and 1¼ per cent for inspection. Notwithstanding these figures, there has been a very considerable increase of efficiency during the biennial period ended October 31, 1916, over the biennial period immediately preceding it, for the reason that during the latter 136 pieces of work of an aggregate cost of $3,222,378.81 were handled, and during the former 124 pieces of work, or only 12 pieces of work less, of an aggregate cost of only $1,364,420.34, or only a little over one-third the cost, were handled. Furthermore, in the figures above given in connection with both the biennial periods, and on which the percentages are computed,

"days labor" work, for which the bureau acts as contractor and builder, as well as architect, are included; during the period ended October 31, 1916, the expenditure for this "days labor" work was $216,055.26, whereas during the period ended October 31, 1914, only $163,973.81 was expended in this way. Also, during the period ended October 31, 1916, our overhead for this "days labor" work was greatly increased on account of going into greater detail than before, in getting bids, with the result that the bids themselves have been much lower, having much more than offset the increase in our overhead.

The schedule of proper minimum charges of the American Institute of Architects, which schedule today governs the practice of all our best architects, makes 6 per cent of the total cost the architect's minimum compensation in any case, and where the work is of small cost, and in connection with the remodeling of existing buildings, 10 per cent and sometimes 15 per cent of the cost is paid; the institute's schedule also provides that the owner, in addition to this percentage payment, shall defray the expense (amounting to about 1 per cent of the total cost) involved in securing special expert service covering structural engineering and mechanical engineering, which latter includes power plants, heating, ventilating and electrical engineering (all of which items are included in the 5.10 per cent above mentioned), also the expense involved in the continuous service at the building site itself of a clerk of works or superintendent of construction, which corresponds to our expense for inspection. In cases where the architect acts also as general contractor, which cases correspond to our "days labor" work, the builder's fee of 10 per cent is added to the fee of the architect, thus making the total cost, outside of that of the special expert service above referred to, 16 per cent; this "days labor" work as done by the Bureau of Architecture was included as above indicated in arriving at the average cost of 5.10 per cent already mentioned.

As a means of increasing efficiency, we are putting into effect a change in the organization of the entire Department of Engineering. A Review Board, composed of the State Engineer, the State Architect and the heads of divisions, has been formed and meets monthly. Committees, composed of the various members of the board, consider and make suggestions regarding the different branches of the department's work, which are discussed by the board and put into effect when they are found to be sound. One of the results of this scheme of organization will be the preservation for the benefit of those who come after the present occupants of the various positions in the department, of the rules and methods of operation which have been proven by experience to be best.

PLATE VII.

Fresno State Normal School.

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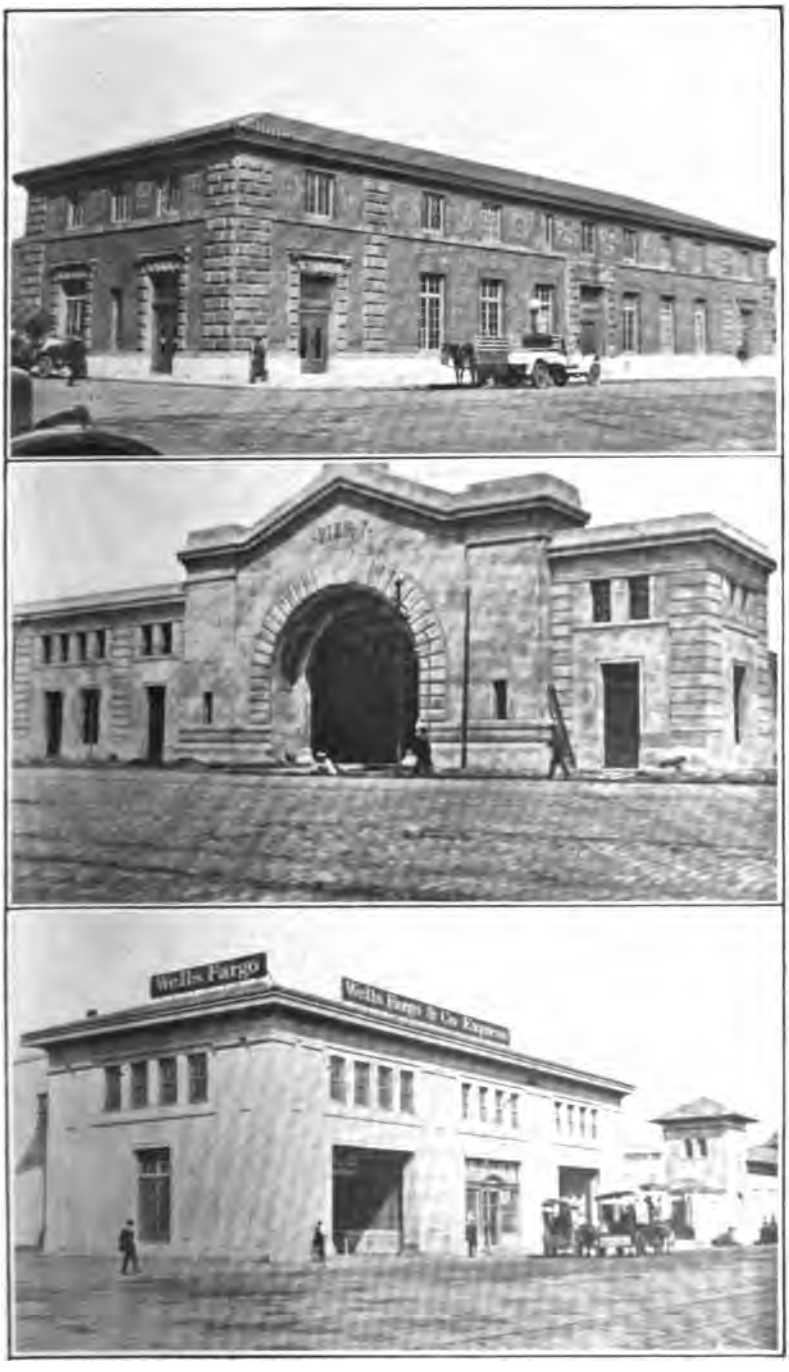
PLATE VIII.



Top—San Francisco Harbor, Post Office.
Middle—San Francisco Harbor, Pier Entrance.
Bottom—San Francisco Harbor, Express Office.

(p. 28)

Under this changed scheme of organization the Bureau of Architecture, as already stated, is responsible for all Department of Engineering work at all the state institutions. The State Architect is the director of the bureau. The Assistant State Architect has general supervision over all the work of the bureau and is chief of the Division of Architecture. The General Superintendent is chief of the Division of Engineering, which includes mechanical, electrical and hydraulic engineering, also all work in the field. This change in responsibility and organization of the Bureau of Architecture is resulting in better control and consequently in increased efficiency in handling the department's work at the institutions.

The state should have the best work in architecture as well as along all other lines. The Bureau of Architecture is securing this kind of work about as follows:

> A full appreciation of the building needs of the various state institutions is secured by frequent consultation with the executive heads and boards of management and by frequent visits of the State Architect and his assistants to the institutions.
>
> The designers in charge of the planning and designing of the buildings, from having been in the state's employ for a considerable length of time, have become specially expert as to the building needs of the state institutions and the best methods of meeting them.
>
> An ample force of draftsmen—architectural, structural, mechanical and electrical—is employed, with the result that working drawings, large scale drawings and full-size details, as the basis for bids and contracts, are thoroughly complete; this is true also of the specifications which form a part of the basis for bids and contracts; the specification writers keep in continuous touch with the market as to all building materials. Since our mechanical and electrical engineers, structural engineers and specification writers, also our cost estimators, work in conjunction with our architectural men—all employees being under the continuous charge of heads of the several divisions—we are especially well situated to secure perfect and complete sets of working drawings and specifications with a minimum of lost motion.
>
> Our drawings more clearly delineate all the details of construction than the drawings which the average architect provides and, on account of the clearness of our drawings and specifications, bidders are able to estimate more closely the cost of the work; the lower bids run very close to each other in practically every case.

The above conditions as to drawings and specifications, taken together with the continual presence at building sites of competent inspectors, make it possible for us with the least friction and expense to secure the completed buildings in accordance with contract agreements. Field inspectors are kept in constant touch with the office, through the supervision of the general inspector, who is connected with the Engineering

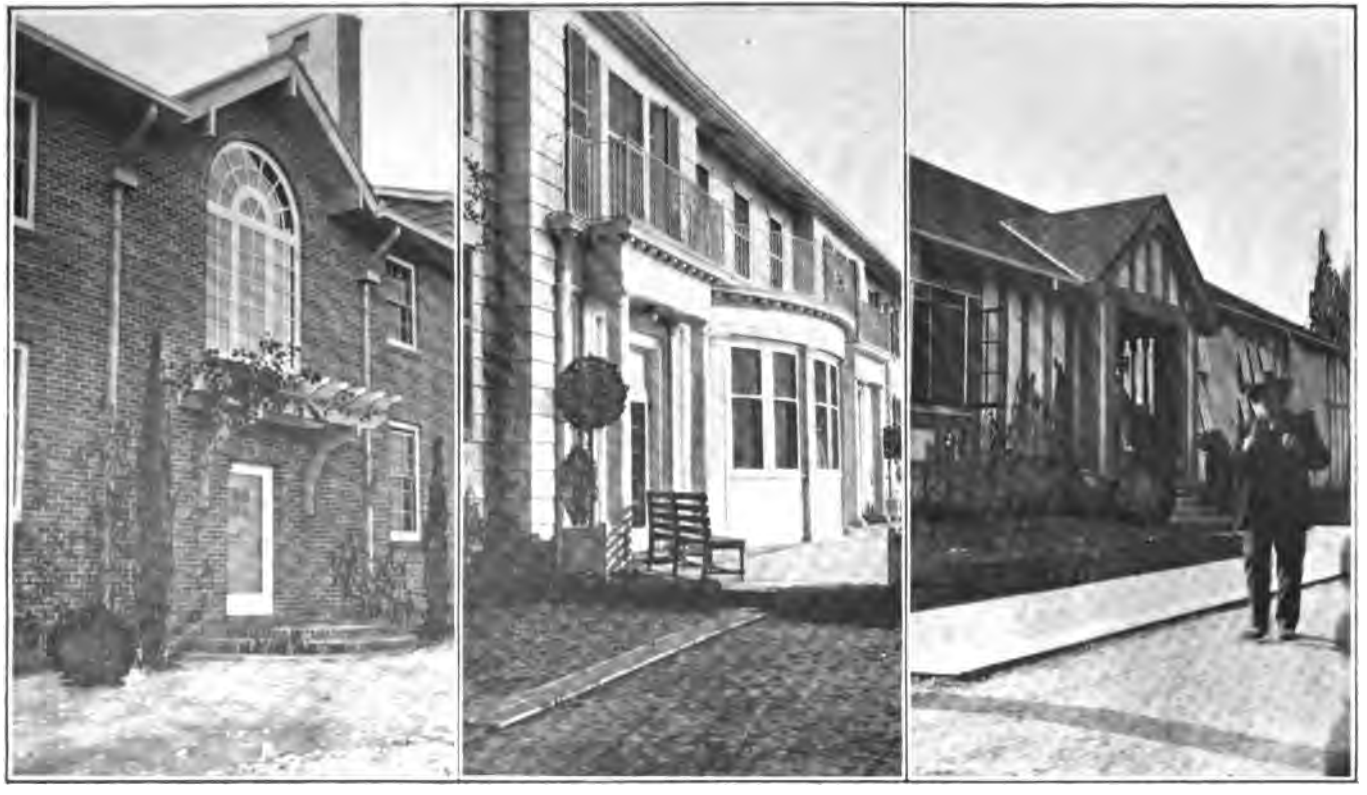
Division. The testing engineer of the State Purchasing Department cares for the analysis and testing of materials entering into the construction of buildings where such analysis and test are necessary to eliminate doubt as to whether quality and combinations of materials agree with specification requirements.

A change was made by the legislature of 1915 in section 11 of the engineering law; this section now provides that the Board of Control, with the approval of the Governor, may, in cases where the best interests of the state require it, arrange for the selection of the architects from outside the Department of Engineering, by public competitions, the State Architect being the architectural advisor of the Board of Control in instituting and conducting such competitions. This course is now being followed in connection with the San Francisco State Building, and is to be followed also in connection with the Capitol Extension buildings to be erected in Sacramento.

The present organization of the Bureau of Architecture of the Department of Engineering and this provision for the holding of competitions provide the means of efficiently meeting all the exigencies of the state's building requirements.

Following is the partial list of construction hereinabove mentioned, with the total cost of each item and the percentage of expenditure for services in the office and inspection in the field:

PLATE IX. ARCHITECTURAL TREATMENT OF ENTRANCES.



Workers' Cottage, Norwalk State Hospital. Hospital, California School for Girls. Ventura. Amusement Hall, Veterans' Home.

(p. 30)

Number	Building	Institution	Cost	Per cent for office work	Expended for office work	Per cent for inspection	Expended for inspection	Total per cent	Remarks
1	Women's Building	State Agricultural Park	$28,500 00	6.66	$1,905 58	2.38	$679 86	9.06	Contract; building completed.
2	Fire escapes	Cal. School for Deaf and Blind	1,500 00	3.45	51 80	1.33	20 00	4.78	Contract; building completed.
3	Garage	California School for Girls	2,500 00	6.86	171 52			6.86	Day labor; building completed.
4	Cottage for males	California School for Girls	5,100 00	8.37	427 10			8.37	Day labor; building completed.
5	Commissary Building	California School for Girls	7,000 00	6.54	458 12			6.54	Day labor; building completed.
6	Farm buildings	California School for Girls	6,000 00	6.82	409 44			6.82	Day labor; building completed.
7	Two cottages and Detention Bldg.	California School for Girls	46,500 00	5.59	2,599 01	3.95	1,836 59	9.54	Contract; buildings completed.
8	Temporary school buildings	Humboldt State Normal Schl.	17,000 00	3.92	666 50	4.55	773 11	8.47	Day labor; building completed.
9	Additions to Manual Arts Bldg.	Los Angeles Normal School	2,500 00	3.89	97 36			3.89	Day labor; building completed.
10	Manor House	Mendocino State Hospital	4,500 00	12.54	564 27			12.54	Day labor; building completed.
11	Additions to Commissary Bldg.	Mendocino State Hospital	14,131 00	3.05	431 75			3.05	Day labor; building completed.
12	Steward's cottage	Mendocino State Hospital	3,000 00	17.07	512 06			17.07	Day labor; building completed.
13	Elevators	Mendocino State Hospital	7,500 00	1.67	125 50	.93	70 00	2.60	Contract; building completed.
14	Additions to South Pay Cottage	Napa State Hospital	15,000 00	5.90	885 52	3.67	550 34	9.57	Contract; building completed.
15	Cottage for men and women	Napa State Hospital	30,000 00	4.12	1,234 70	1.29	388 80	5.41	Contract; building completed.
16	Fish Hatchery buildings	Owens River Fish Hatchery	64,978 00	4.36	2,832 85	3.09	2,006 98	7.45	Day labor; building completed.
17	Class rm. and Domestic Science Bldg.	San Jose State Normal School	18,700 00	6.49	1,262 06	4.97	919 34	11.46	Contract; building completed.
18	Machinery Building	Santa Barbara St. Normal Schl.	7,000 00	4.67	327 23	1.30	91 31	5.97	Day labor; building completed.
19	Girls' Nursery	Sonoma State Home	22,000 00	4.76	1,458 21			4.76	Contract; building completed.
20	Cottages "N" and "O"	S. California State Hospital	41,500 00	3.68	1,526 87	1.51	626 27	5.19	Contract; building completed.
21	New boilers	Stockton State Hospital	7,000 00	1.67	116 69	2.42	169 90	4.09	Contract; building completed.
22	Hay barn	Stockton State Hospital	7,000 00	6.00	420 50	.33	23 00	6.33	Contract; building completed.
23	Electric wiring	Stockton State Hospital	10,500 00	9.90	1,038 06	1.74	183 60	11.64	Day labor; building completed.
24	Cottage for convalescents	Stockton State Hospital	27,000 00	4.15	1,120 10	2.04	551 82	6.19	Contract; building completed.
25	Cottage for male patients	Stockton State Hospital	27,000 00	4.15	1,128 18	3.37	911 30	7.52	Contract; building completed.
26	Ten sanitary cottages	Veterans' Home	22,500 00	4.56	1,251 86			4.56	Contract; building completed.
27	New bath rooms in Barracks	Veterans' Home	15,000 00	4.72	709 17			4.72	Day labor; building completed.
28	Bank screen	State Treasurer's Office, Capitol	3,000 00	3.57	107 17			3.57	Contract; building completed.
29	Painting	State Printing Office	2,000 00	.57	11 39			.57	Day labor; building completed.
	Totals		$466,209 00		$23,790 57		$9,801 72		
					5.10% of cost.		2.10% of cost.		

On the 15 constructions in the above list costing between $1,000 and $12,500 the percentage for office work was 6.36; for inspection was .73.
On the 5 constructions in the above list costing between $12,500 and $20,000 the percentage for office work was 4.89; for inspection was 2.82.
On the 9 constructions in the above list costing between $20,000 and $70,000 the percentage for office work was 4.85; for inspection was 2.25.

PART II.

HYDROECONOMICS.

Every body of water has its uses, and often one body may have several uses, all contributing to the welfare of man. Broad arms of the sea, stretching inland, offer easy highways for cheap communication and transportation for the communities along their shores. Broad rivers afford like facilities for commerce, and also furnish water for irrigation of the lands along their banks to produce that commerce. Tributary streams contribute power for lighting the streets and homes of communities created by the benign influences of the others, as well as operating the myriad wheels of industry. And all unite, in the mad moods of nature, to send destruction and ruin upon the works of their beneficence.

Each body or stream has problems of its own to be solved that its forces may be directed to beneficial use, some akin and some dissimilar in the methods of their solution.

SACRAMENTO RIVER PROBLEMS.

That in the Sacramento Valley lies a million acres of land periodically laid waste by the flood waters of the Sacramento River is too well known to need extended mention here. That concrete effort is being made to rescue that vast body of land from waste and convert it into an asset to the state is also known; but the method by which it is proposed to accomplish that object is not well understood by all. Indeed, many who are directly connected with the reclamation of the Sacramento Valley and the control of its rivers, misunderstand the plan and how it is to be carried out.

The Sacramento River traverses the valley for a distance along its course from Red Bluff to Suisun Bay of 264 miles. The banks of the river are higher than the land some distance away on either side between the river and the uplands rising to the foothills. This condition creates a long, wide trough on each side. Tributary streams entering at intervals have built up delta ridges across the troughs, converting them into basins. A notable example of this is the Knights Landing ridge which divides the west side trough into Colusa and Yolo basins. The channel of the river, occupying the ridge between the two troughs, is limited in its capacity to carry water.

From Red Bluff to the confluence of Stony Creek the water keeps well to the channel, but below that point the capacity is reduced, and flood waters are spilled over the banks into the basins. From Colusa to Feather River the capacity of the Sacramento River between banks is

only 30,000 second-feet (cubic feet per second), while the records show that at Iron Canyon the flood flow has reached 254,000 second-feet, which flow was augmented by the waters of Stony Creek and other smaller streams on the west and by Mill Creek, Antelope Creek, Chico Creek and others on the east, all running large volumes not measured. Without including these numerous additions it is seen that the volume of water entering the upper reaches of the river is eight or ten times the capacity of the river through Glenn and Colusa counties to carry it.

Any water in excess of 30,000 second-feet must, of necessity, spill over into the basins at each side. These basins contain the most fertile land in the valley and their owners have for many decades endeavored with varying success to build levees around them to keep the water off. So long as these efforts were confined to small areas, little effect was had upon the flood plane of the water occupying the unreclaimed remainder, but as the levees were extended, joined together and made continuous, holding the water within narrower areas, the flood plane rose until it overtopped or breached the works confining it, and again inundated the basins. This happened again and again, and the conditions became more and more aggravated as the storage way in the basins was reduced.

As the river progresses down the valley its volume grows greater, the Feather River enters it, bringing the water from its own watershed as well as from the Yuba and Bear rivers. It is joined just above the city of Sacramento by the American River. The measurements of flood flows show that the influx of water to the valley from Red Bluff to Sacramento has amounted to 550,000 second-feet. The river channel at and below the city has a carrying capacity of only a little more than 100,000 second-feet, or about one-sixth of the quantity that would have reached Sacramento in the floods if it had not spread over the basins on each side, and been stored there to run off gradually.

Engineers have estimated that floods occurring before measurements were undertaken have reached a flow of more than 800,000 second-feet in the valley.

Whenever the waters leave the river to reach the basins they erode channels which continue to carry water after the water of the stream has receded within the banks of the river. Such division of the mid-stage and low water flow causes bars to form in the main river and impedes navigation. To prevent injury to navigation the integrity of the banks of the river must be maintained and side channels never allowed to reach the low water plane so as to divide the waters needed for the carriage of boats.

Many engineers and commissions have given study to the problems involved, and all agree that the only way to protect the low lands from

inundation is to provide channels through them to carry away the water that has spilled over the banks of the river. And to preserve the navigability of the river its banks must be held intact by providing indestructible weirs for the passage of the excess waters.

The government in 1893 created the Debris Commission and directed it to devise means of controlling the inflow of mining debris from the mountains and of improving and maintaining navigable conditions on the rivers. After seventeen years of study, experiment and research the commission presented a plan[1] to effect the objects for which it had been created.

While the duties imposed upon the Debris Commission were confined to devising means to aid navigation, the report submitting its plan declares that there is no other way known to the commission by which navigation can be maintained and improved except the one offered which involves flood control of the streams and reclamation of the lands. Since the works necessary to improve navigation would benefit other interests it was considered that the cost should be borne by all who are to receive the benefits, *i. e.*, the government, the state and the landowners.

The plan is to construct strong levees on each bank of the river so as to make the channel carry all the water possible with safety. To construct concrete weirs at selected points through which the excess waters will be discharged under control. To construct artificial channels through the basins of ample dimensions to carry the waters turned out of the river. To bring all of the waters together at the outlet of the valley, and to enlarge the outlet so as to freely discharge the accumulated waters without "backing" them up in the channels above.

The cost of the works as planned was estimated at $33,800,000, and it was recommended that the government pay one-third and the state two-thirds. In alloting two-thirds of the cost of the work to the state it was thought that it would be equally divided between public appropriations and assessments upon the lands benefited by permanent reclamation.

The report was transmitted to the House of Representatives on June 27, 1911, and two days later referred to the Committee on Harbors and Rivers.

An extra session of the legislature being called to consider other matters, the Governor included in his proclamation commendation of the commission's flood control project for consideration.

By an act approved December 24, 1911,[1] the report of the Debris Commission was approved with such modifications and amendments

[1]Chapter 25, Statutes, extra session, 1911.

as might be found advisable as a plan for controlling the flood waters, improving navigation and reclaiming the overflow lands.

Thus, for the first time in the long history of this matter, did the state of California adopt a policy and commit itself to a definite method of procedure. In addition to approving the report of the commission the act created a State Reclamation Board to carry the project into effect so far as concerned the state's share.

This board was given jurisdiction over any plan of reclamation undertaken on the Sacramento and Feather rivers in order that such plans should not conflict with the flood control project as approved or to be modified and amended by the board. The State Engineer was directed to procure data and make such surveys as might be required to enable the Reclamation Board to prepare details for the proposed plans.

The adoption of a settled policy of state control over reclamation and flood control in a way that gave promise of absolute protection greatly stimulated individual effort along those lines. Indeed, so actively did private interests enter upon the reclamation and so diligently did they prosecute extensive plans, approved by the Reclamation Board so as to not only avoid encroaching upon the Debris Commission plan, but on the contrary to form part of those proposed works, it was soon found that a great deal of the public work planned by the commission was being done by private enterprise, making it possible to eliminate much of the cost estimated in the commission's report of 1910. Thereupon, the Committee on Rivers and Harbors of the House of Representatives on December 2, 1912, requested the Board of Engineers for Rivers and Harbors to review the report embodied in H. R. Document No. 81, 62d Congress, and to report subsequent information and conclusions thereon.

In compliance with that request the Debris Commission reported February 8, 1913, giving account of the tremendous development above mentioned and the great progress made toward accomplishing the end sought in its former report. The commission estimated that in view of what had been accomplished and the work already planned by private enterprise, the joint governmental costs to complete the works for the control of debris and floods and improvement of navigation according to the plans contemplated in its 1910 report would be $11,717,000, not including the $800,000 appropriated jointly for work at the mouth of the river, and not including costs for rights of way.

The commission recommended that one-half of the estimate, or $5,858,500 be paid by the United States and the other half by the state, and that all rights of way be furnished without cost to the United States. It will be seen from the above stated figures that the national government's share of the cost has been reduced nearly one-half. The

land owners, however, will not be so fortunate, since they are expected to procure the rights of way and the price charged for the land to be taken will far exceed the prices considered in the original estimate.

The $800,000 mentioned above as having been formerly appropriated jointly by the United States and the state was for initial work in enlarging the mouth of the river as recommended in a preliminary report of the Debris Commission made in 1907. Making the mouth of the river larger is a necessary part of the adopted scheme as foreseen in the preliminary report and incorporated in the subsequent reports.

With the funds appropriated two large suction dredges, the *Sacramento* and the *San Joaquin*, were built, and have been operating since the summer of 1913, with funds appropriated from time to time by both congress and the legislature.

The necessity for enlarging the mouth of the river in advance of the completion of the controlling works in the valley above is apparent upon consideration of the physical conditions existing. It was stated that the measured flow of floods has exceeded 600,000 second-feet, and that quantity was used as a basis for the works planned by the Debris Commission.

The greater portion of that vast volume of water was spilled by the river into the basins, which became, then, regulating reservoirs, holding back the floods so they traveled but slowly down the valley. The construction of works to direct that water into unobstructed channels will increase the rapidity of its progress and bring it all together at the outlet.

Before work of enlargement began, the width of the river between Bakers Point on Sherman Island and the Montezuma hills was only about 750 feet with a cross-sectional area of about 33,000 square feet. So long as the waters were held back in the basins and fed out gradually they could escape through the contracted way, but when given quick transit to the point of exit so small an opening would cause disaster to all adjacent country.

The work accomplished has been the moving back of the levees on Sherman Island and the excavation of a channel across the chord of Horseshoe Bend below Rio Vista. The effect of this work is noticeable in the rapidity of current in the river above, even as far as the city of Sacramento. The operation of the dredges is in the hands of the Debris Commission, and details thereof will be found in the report of the commission to be found at the close of this article.

The surveys and investigations made for the Reclamation Board showed that complete control of Sacramento River could not be effected until the floods of the San Joaquin were also brought under subjection.

The act establishing Sacramento Drainage District and creating the Reclamation Board was amended in 1913 (chapter 170, statutes 1913),

enlarging the district to embrace the San Joaquin overflow region up to Fresno County, naming it Sacramento and San Joaquin Drainage District, and enlarging the Reclamation Board from three to seven members.

The State Engineer is directed to gather data, make surveys and investigations for the formulation of plans for the improvement of navigation and the reclamation of lands subject to inundation in both valleys.

The enlarged district lies in fourteen counties and embraces 1,726,553 acres.

SAN JOAQUIN VALLEY FLOOD PROBLEMS.

The area of the San Joaquin Valley is more than twice that of the Sacramento Valley, and the San Joaquin River has many more tributaries from the Sierras than has the Sacramento. The aggregate quantity of water furnished by the San Joaquin and its tributaries, however, is much less than that furnished by the Sacramento. The average annual run-off reaching the Sacramento Valley is 27,000,000 acre-feet, while that of the San Joaquin is a little less than 14,000.000 acre-feet.

The maximum recorded flood flow of the Sacramento exceeded 600,000 second-feet and estimates of unmetered floods require plans for works to care for 800,000 second-feet, while the records of maximum flood flows in the streams entering the San Joaquin Valley aggregate 325,000 second-feet. Moreover, topographic conditions divide the valley into three districts, each having its own flood areas and only in exceptionally high floods do they unite their waters.

Unlike the Sacramento, the San Joaquin River occupies the trough of the valley, and has not built up a ridge in its course to create basins at the side. The inflowing streams from the sides, however, have built up delta cones, which meeting from opposite sides form ridges across the valley, thus dividing it into basins.

The general shape of the valley is that of an elongated ellipse, extending from the foot of Tehachapi Mountains in a northwesterly direction to a junction with the Sacramento Valley at the confluence of the two rivers. the dimensions being about 270 miles in length and 20 to 60 miles wide, and embracing 7,500,000 acres as against 3,500,000 acres in Sacramento Valley. About two-thirds of the valley lies on the east of the trough, and one-third on the west.

Several streams fed by the snows of the Sierras enter from the east, but those on the west having their origin in the low arid Coast Range furnish no considerable amount of water to the San Joaquin River.

Kern River enters from the east some 30 miles from the extreme head of the valley. It has built a delta cone entirely across the valley to the foothills on the opposite side and formed a basin within which its waters

are impounded. The lowest bottom of the basin is marked by Kern and Buena Vista lakes. When excessive floods have filled the basin to overflowing the waters flow northward in Buena Vista Slough.

Kings River enters the valley some 75 miles from Kern River. This stream has built a large cone into the valley which, meeting a similar one from Los Gatos Creek on the west, has formed a ridge which creates a basin south of it of which Tulare Lake is the bottom. The summit of this ridge is about 30 feet in elevation higher than the bed of Tulare Lake at its lowest point and some 60 feet higher than the bed of San Joaquin River to the north.

San Joaquin River, entering 20 miles* north of Kings River, runs in a course perpendicular to the axis of the valley 30 miles or two-thirds of the way across, where it turns abruptly to the right and continues thence in the trough of the valley.

Thus it is seen that Kern and Kings rivers deliver their waters into separate basins presenting separate problems of control from those of the San Joaquin River to the north.

Although each section has the problem of protecting its lands from its own waters, San Joaquin is menaced by the occasional filling of Tulare Lake to overflowing and discharging its floods into the swollen waters of San Joaquin, and likewise Tulare Lake floods are augmented by the escaping waters of Kern Lake basin. Furthermore, both Kern and Kings rivers sometimes divide before reaching their respective basins, and by delta channels discharge part of their floods over the ridge into the adjoining territory—Kern River into Tulare Lake and Kings River into San Joaquin, and if Tulare Basin is already full when Kern River water reaches it that water then adds its volume to the water flowing into the San Joaquin.

It has been stated that investigations for the Reclamation Board showed that complete reclamation and flood control of the Sacramento Valley could not be effected without also controlling the waters of the San Joaquin.

From the above discussion it also appears that flood control works on the San Joaquin must be constructed to care for additional waters from Kings River and Tulare Lake as well as some from Kern River, and that any scheme for flood control and reclamation in Tulare Lake basin must also consider the necessity of providing against injury from the excess waters of Kern River.

The correlation of all the problems presented, and their correct solution by the design and erection of works adequate to reclaim and render safe against floods of more than 3,000,000 acres of valuable land with its hundreds of homes, and a score of cities and towns, does not

*All of these distances are air-line measurements, scaled from the map and are only approximate.

appear to be possible excepting through the agency of a single directing body with large powers.

The state has been for years gathering data which will be useful in devising a comprehensive flood control project for the San Joaquin Valley.

Some years ago civic bodies in the valley induced the United States congress to appropriate funds for investigating the feasibility of restoring navigation on the San Joaquin River. That appropriation in the sum of $32,277.50 was made in 1912, and coupled with the provision that the state should furnish an equal amount. There being no appropriation available, the Department of Engineering joined with the United States army engineers, and allotted the sum of $32,277.50 from its funds to meet the government appropriations, making a fund of $64,555 for the purpose.

Surveys and research were made, covering the topography of the valley subject to inundation, the stream flow of the river and its tributaries, the possibility of increasing the summer flow by means of storage, the feasibility of providing navigation by dams and locks, and all other subjects relating to canalization, as well as the control of floods in aid of navigation. The studies made in connection with the survey extended to the partial consideration of Kings River and Tulare Lake and their relation to San Joaquin River.

The Department of Engineering in its general studies of the subjects of canalization, irrigation and reclamation, apart from the specific subject just mentioned, has collected considerable data concerning conditions affecting Tulare Lake and has extended its research to the flood waters of Kern River reaching the lake.

All of the data collected by both the above named agencies are being analyzed and studied by this department in connection with its work with the Reclamation Board for the Sacramento and San Joaquin Drainage District.

If the plenary powers possessed by the Reclamation Board concerning the affairs of the Sacramento and San Joaquin Drainage District were extended to the territory against whose assaults defensive works must be designed, it would result in complete correlation of all interests, the equitable division of costs, and the ultimate construction of one comprehensive system of works insuring safety to 2,000,000 acres of fertile land, and hundreds of miles of navigable channels extending through a territory as large as either the kingdom of Holland or of Belgium.

While this report can not with propriety forecast the recommendations to be based upon the investigations made in cooperation between the army engineers and the state, under the joint appropriations above described, the department's independent research warrants the belief that when navigation shall be developed throughout the interior to the

fullest extent attainable at cost commensurate with the benefits to be derived *all debris-carrying flood waters will be excluded from ship channels.* Such exclusion can be accomplished in the San Joaquin Valley at least as far up as Stockton by a system of by-pass channels through the delta regions.

The further discussion of this phase of the subject will be resumed herein in another chapter devoted to navigation.

The details of engineering work in connection with the operations of the Sacramento and San Joaquin Drainage District it is not considered necessary to recite here, but their description is left to be set forth by the Reclamation Board in its report of its administration.

FLOOD PROBLEMS OF OTHER STREAMS.

Nearly every stream which traverses populated territories, whether large navigable rivers or intermittent streams flowing only a part of the year, at times visits danger and destruction upon the communities along its course.

The Colorado River, from the waters of which the great Imperial Valley is irrigated, in 1904 forsook its channel to the Gulf of California and created havoc and destruction in its way to Salton Sea. The task of changing it back to its old course required several years of continuous effort and the expenditure of millions of dollars.

The efforts of Imperial Irrigation District have at last resulted in complete control of the Colorado with works that give promise of permanence and efficiency.

Los Angeles and San Gabriel rivers have both been on the rampage several times within the last few years, doing damage amounting to many millions of dollars.

The Santa Ana has also contributed to the destruction of lands and orchards which its waters in their benign moods have created.

The San Diego, Sweetwater and Tia Juana rivers and in fact all of the streams of San Diego County a few months ago were filled with unprecedented floods, washing out railroad and highway bridges and doing a vast amount of other damage.

In the northern part of the state, Mad River and Eel River, both in Humboldt County, have from time to time risen in their might, and in addition to carrying away bridges and houses have attacked the rich lands along their banks, washing whole farms into the sea. These streams with their steep gradients and swift currents, great redwood trees riding the flood waves, attack all protective works with well-nigh irresistible force. Only the most substantial bulwarks can resist the blows of those huge battering rams.

There are several laws under which communities may organize to construct protective works. Two or three forms of reclamation districts

are provided, flood protection districts may be organized, but all are for action upon a unit basis.

Experience has abundantly proven that when a given community shall effect its own protection that very fact often constitutes a menace to other communities. The reclamation of a body of land over which flood waters are accustomed to flow necessarily compels those waters to go elsewhere. As other reclamations are completed the waters become more and more concentrated, the flood plane is raised, requiring higher and stronger levees to be built by the first as well as the new reclamationists. The water being held in confined channels rushes with greater speed and volume to lands below, to the destruction of any feeble works that may have been erected and rendering reclamation impossible.

Every problem of flood control must be worked out according to the conditions present, and always with reference to its effects upon others. If a given community can effect protection for itself without affecting others outside its boundaries, it should have absolute autonomy in all its affairs. But if its methods shall result in injury to persons or property outside its territory, then those threatened with injury must be protected, and the contemplated works so planned as not to damage the neighbors.

It would seem as though all reclamation and flood protection schemes might be conducted under one law better than under so many, and it is hoped that the Water Problems Conference will present to the coming legislature recommendations for simplifying the laws and placing the matters on a common-sense, workable basis.

TULARE LAKE FLOODS.

The close relations existing between the flood problems of the San Joaquin River and of the Tulare Lake and Kern River basins has led the Department of Engineering to devote special study to the latter. Records of stream flow measurements have been kept jointly by the department and the United States Geological Survey for many years. These measurements are made at the mouths of the canyons where the streams enter the valley and do not indicate what becomes of the water after it passes the gaging stations, excepting that stations have been maintained at Tulare Lake from which a record is obtained of the fluctuation of that body.

Kings River.

From notes in the Department of Engineering the following description of early conditions on Kings River are compiled:

This stream debouches from the mountains near Centerville, about 25 miles east of the city of Fresno, and for 25 miles runs between banks 20 to 50 feet high. Near Kingsburg the banks diminish, and thence begins the delta fan built by the waters of the river. This fan, its apex at the miniature gorge just described,

spreads downward toward the central trough and left and right over the plains. It is this fan meeting a similar one built by the waters of Los Gatos Creek opposite, which forms the ridge dividing Tulare Lake from San Joaquin River.

In the early days of settlement in this region the channel of Kings River was well defined all the way to Tulare Lake. In the upper portions of the delta the branch channels were small and carried but little water. A survey of the lands lying in the delta and west and north of the main river was made by the United States Surveyor General in 1864, and the meander line ran along the right bank of the river from just below where Kingsburg is now, necessarily crossed all streams branching off toward the west. According to the notes of this survey, Cole Slough, which now carries all of the summer flow and the major part of flood, did not exist. A short distance farther down the river a small channel branched off and ran west, but it was only a small channel. The same with all other channels branching off.

The survey followed the river to its confluence with the San Jose Slough and thence ran northwest to Summit Lake. Thence the course of the survey was northeasterly across the swamp and it is notable that no streams or channels were noted where the line now crosses North or Beall Slough, nor was any other channel discovered in a distance of several miles and reaching beyond the swamp meander line. This is only cited as corroborative of the claim which is made with the force of conviction that in those days all of the low and medium flows and nearly or quite all of the flood waters of Kings River flowed south to Tulare Lake and it was only when the lake had filled to overflowing that water from Kings River ran into the San Joaquin, and then only after mingling with the waters of Tulare Lake.

The most easterly branch of the river which diverted flood waters was Burris Slough which diverted from the left bank three or four miles down the "fan" from the present head of Cole Slough. This channel was one of the earliest of those running south to be closed by man, and water prevented from running in it. This was done about 1873. Mussel Slough, some three miles farther down, was converted into a ditch and a headgate placed in it. The headgate becoming decayed and the ditch having ceased operations, a dam was constructed across, effectually closing it. In the meantime, levees had been built across all depressions by which high water could escape. Leinberger Slough was put under control as a heading for a ditch, as also Carothers Slough, which became the intake of Rhoads Ditch. Both Leinberger and Carothers sloughs returned to the river several miles below and before it reached the lake, but the others had originally run to the lake without again reaching the parent stream.

As previously stated, Cole Slough is the first branch from the river. The original Cole Slough was very small, but the flood of 1867 opened up the present channel about a quarter-mile upstream. It has been enlarged by each recurring flood until now it is by far the larger channel.

Several miles below its head where the slough approached near to the river a settler had built a fence of poles and stakes with a ditch alongside to render it a greater barrier to stock. During the floods the water found this ditch and quickly enlarged it until now it is several hundred feet wide and several feet deep. It is called Dutch John Cut.

Murphy's Slough, a branch of Cole Slough, approaching within a few rods of the river at one point a mile or two above the present town of Laton, broke back into the river. The channel thus made, called Reynolds Slough, has long been controlled by a gate in it.

Some four or five miles below the old deserted village of Kingston, founded in the "fifties" at Bliss Ferry where traffic crossed the river to follow the old overland route to Texas, a channel branched off and ran west. It was known as North Fork. This stream was reported by the survey of 1864, heretofore referred to as being about 80 or 90 feet in width on top, if memory serves correctly. It ran straight west for some distance and then bearing toward the northwest must have discharged water, when it carried any, into the San Joaquin through Fish or Fresno Slough. It was closed off with a dam, however, in 1865 or earlier.

After the North Fork was closed, J. G. James, who owned a large tract of land along Fresno Slough, constructed a ditch diverting from the river about two miles

above the head of North Fork and conveyed water to the west. In 1879 or 1880, the headgate in the James canal was washed out and another constructed. This was soon wrecked and then the owners of the "Grant" as the rancho on that side of the river is called, filled in the head of the canal.

About 1½ miles below the closed head of the North Fork another canal, called the Zalda, was constructed, running west. The flood of 1879 washed around the headgate in this ditch and considerably enlarged the canal below. About half a mile below the head of the Zalda canal, the Crooked Slough diverted on the opposite side of the river. This slough rejoined the river several miles below, but its head was used as the intake of the Rhoads ditch. A brush dam was maintained in the channel of the river to force low water into the head of Rhoads ditch.

In the spring of 1884, the highwater washed the headgate out of Zalda canal, and again enlarged that channel. At the same time, or perhaps subsequently, the Rhoads dam, checking the water in the river, caused that channel to fill completely with sand and debris, shutting off all flow to the south and making the Zalda canal the only river. The course of the Zalda canal toward the west crosses many swales and depressions, all running toward the south, and when the canal became the river, which, notwithstanding its enlargement, was unable to carry all the water, it spilled over in the low places and the water found its way to San Jose Slough and thence back to the old river channel several miles below and thus into Tulare Lake. Some of these escapes soon cut out quite large channels leading south. One or two of them terminated in the shallow basin on the summit of the divide hereinbefore referred to as Summit Lake.

The original Zalda ditch very probably terminated in Beall Slough, which was a more or less defined channel traversing the swamp in a northwesterly direction and finally reaching Fresno Slough. The Zalda channel now loses its name and becomes known as Beall Slough.

Shortly after the river changed its course the people interested about its mouth, finding the channel completely filled for half a mile and concluding that to clean it out and restore it to original condition would be too expensive, excavated a narrow cut between the Zalda channel and the river, thus turning some water down their way. This excavation, however, was never made to the same depth as the Zalda. This cut was wholly on the lands of the "Grant" and having been made without authority of the owners, the "Grant" people immediately constructed a headgate in it and secured an injunction from the courts restraining the other people from interfering with the headgate or enlarging the cut. The injunction was later modified permitting the lower-river people to have some of the bottom flash boards removed, but the floor of the headgate remains higher than the bottom of the Zalda channel. Several things now combined to keep the major part of the water running west. The maintenance of the flashboards in the headgate; the higher elevation of the bottom of the cut; the lodgment in the throat of the cut of a large drift of logs and brush which was allowed to remain there, retarding flow into the cut.

Whereas formerly all of the low water naturally ran south, the result of the several conditions enumerated was that all of the low water ran west so that it required something like 700 second-feet before any would run down the old river through the cut. A portion of this water would run into Summit Lake and when that basin had become full it would overflow and run into Tulare Lake. The owners of the "Grant" constructed canals diverting from the Zalda to irrigate their lands on the "Island" the triangular shaped tract of land lying between the river on the east, San Jose Slough on the west and Zalda canal on the north, comprising some 10,000 or 12,000 acres.

For many years the conditions stated caused a division of the water to be such that about one-third to one-half of the lower flows would reach Tulare Lake. Then when the spring freshets came about one-third would run through the cut, two-thirds west in the Zalda and about one-half of the Zalda water would be returned through Summit Lake and San Jose Slough to the river to be conveyed to Tulare Lake.

In 1903 the "Grant" constructed a levee along the south side of the Zalda, closing off nearly all of the channels and depressions that had formerly taken its surplus

water to the south. One or two were left open and up to about 1912 or 1913 ran some water into Summit Lake.

In addition to the levee which has retained more water in the channel, a great deal of work has been done in the channel itself, or at least in the Beall Slough portion, all of which it is claimed, and apparently the claim possesses logic, that the Zalda has constantly increased in capacity until now it carries all of the water at low and medium stages and from 65 per cent to 80 per cent at any stage. Originally, and up to the scouring out of the old Zalda ditch and the choking of the main river the flow was the other way—all the low water ran south, else James would not have built his canal many miles in length nor would the Zalda ditch have been constructed excepting to obtain water that otherwise would not run west.

In times of flood the river overflowed its banks all along both sides, and old Cole Slough carried water to the west, filling up the low lands north of Laton. This water was drained off, partly into the river again by Reynolds and other sloughs, partly by Murphy's Slough, which continued westward and undoubtedly contributed some to the Fresno Slough and San Joaquin. On the opposite side surplus water found outlets in Burris, Mussel, Wilson and Leinberger sloughs. Further along the by-channels became more numerous. On the south side were Carothers, Crooked, Green, Button Willow and a score of other streams, named and nameless, making a complex network of channels. As the country became settled these sloughs were closed with dams or headgates to protect and reclaim the lands, as all of the lands traversed by them below Kingston were swamp and subject to acquisition upon being reclaimed from overflow.

TULARE LAKE.

Tulare Lake was described in the school books of fifty years ago as being "the largest body of fresh water west of the Mississippi River, 60 miles long, 30 miles wide and of unknown depth." The surface dimensions stated were not far wrong. Taking the margin of the lake as meandered by the government surveys in 1852–54, the area was about 800 square miles. At that time the lake was full and the waters ran over the ridge into the San Joaquin River. Its greatest depth was about 35 feet.

The survey of swamp meander lines was made in 1852–53–54 following the flood of 1852, so that the line probably indicates very closely the extreme highwater mark.

It is known that the lake has long been subject to great fluctuations in area and depth, filling to overflowing at times of great floods and shrinking to little or nothing when its supply was diminished by a series of dry years. History records floods in the state in 1852, 1862, 1867, 1879, 1884, 1907 and 1909. Indian tradition indicates that 1805 and 1833 were also years of extraordinary high water. According to legend the quantity of water in the Kaweah River in 1883 was much greater than any flood has produced since.

The Indians had traditions, too, that their fathers had walked across Tulare Lake dry-shod. Evidences of Indian habitation at points on the bed of the lake show that the margin of the water had remained for some considerable periods at different elevations. Hieroglyphics on rocks in the foothills east of the lake have been interpreted to read that the people were compelled to emigrate from the lake region because all

the fish had died and the people had gone to the mountains for food. To this day when the lake waters recede to a small quantity enormous quantities of fish die in the stagnant pools.

The fluctuating of the lake from full to dry and back to full again is an old story being repeated at irregular intervals, and no one need hope to effect permanent reclamation of any portion of the lake bed until it is all reclaimed under one comprehensive scheme, which scheme must involve the control of the flood waters of the streams whose waters make the lake.

The flood of 1867 was the last to fill the lake to overflowing, and about 1870 the waters began to recede, never regaining their former lines. The entire area embraced within the government meanders was granted to the state under the Swamp and Overflow Land Act of 1850. As the water receded the uncovered lands were taken possession of under the provisions of reclamation laws.

Under these laws one could buy from the state in tracts of 640 acres, later reduced to 320 acres, at one dollar an acre, by paying 20 per cent down. The remaining payments could stand indefinitely. The purchaser could obtain letters patent to the land upon paying the remaining 80 cents an acre. Should he elect to reclaim his land from its overflow condition, upon presentation of proofs satisfactory to the county board of supervisors that it was reclaimed, he not only obtained title but his payments were refunded to him. He could make the reclamation alone or join with his neighbors in a district.

Many districts of all sizes were formed on the bed of Tulare Lake, ranging from 640 to 50,000 acres. Levees were built to keep off the waters. Most of these efforts were honestly intended, though many were frauds. Instances occurred where proofs were tendered and allowed, that lands were "reclaimed" when the extent of reclamations was a backfurrow run around the land with a ten-inch plow. Perhaps, since the water of the lake was several miles distant, such a claimant eased his conscience by the reflection that his backfurrow was sufficient for protection against overflow from a *dry lake.*

The gradual diminishing of the lake area continued with seasonal fluctuations until in 1898 the bed was nearly dry and a large part under cultivation to wheat, barley and alfalfa. Then came a series of prosperous years to the settlers. Farms were established and improvements erected all over the lake bed.

In 1901 the water came and flooded a large area, but again subsided, and in 1905 the lake bed was again entirely dry. But disaster was due, and on March 15, 1906, water again found its way to the lake, and by June 200 square miles had been inundated, a very large proportion of which was again in growing grain, which before the advent of the water gave promise of a "bumper" crop.

The remarkable flatness of the lake bed may be realized when it is remembered that at a depth of two feet, 60 square miles are covered with water, and is practically without slope in any direction.

In June, 1906, Kern basin overflowed and reached the lake through Buena Vista Slough. This was said to be the first time in more than 25 years that Kern River water had flowed into Tulare Lake. Other streams which had not reached the lake for many years contributed, and by August, 1906, the water had reached a maximum depth of 12.7 feet and an area of nearly 300 square miles. The water slightly receded the following months, but rose in the spring of 1907 to the highest stage recorded in recent years, when it reached a depth of nearly 14 feet. It began falling at once, however, and in November of that year a careful survey found the lake had an average length of 20 miles, width 13.5 miles, depth 12.4 feet and area 274 square miles. In December, 1908, the water had receded to 8.3 feet depth, rose to 13 feet in June, 1909, and stood practically still during that summer, declining to 9.35 feet in December, 1910.

Looking forward to the time when all of the interests involved will be united to secure immunity from devastating floods the department has been putting forth extra effort to obtain data that would be useful in solving the problems of reclamation and flood control in the Tulare Lake region.

During the spring of 1916, Mr. J. B. Brown, hydrographer, was detailed to make investigation of conditions affecting reclamation in Tulare Lake basin, and his reports thereon are here presented, practically verbatim:

Flood Conditions of Tulare Lake, 1916.

This report is a summary of the field investigations of certain streams of Tulare Lake basin for the year 1916. The heavy rains of January, 1916, in the southern part of the San Joaquin Valley swelled the streams draining into Tulare Lake to their maximum capacity. Instead of being flash floods the flows were well sustained and by March 1st it became evident that considerable land in the lake bottom was in danger. These conditions led to the setting aside of funds for the purpose of studying stream flows with an idea of using the data thus obtained for the future planning of a comprehensive flood control scheme for the whole basin.

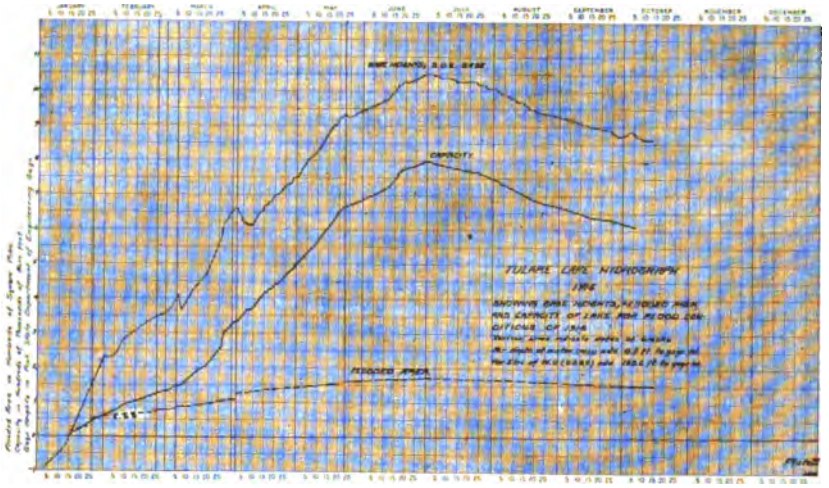
The State Department of Engineering commenced field work on March 23d, by establishing gaging stations on Buena Vista Slough, Tule River and the three channels of Cross Creek. Investigations on the flows of the South Fork of Kings River had been in progress since 1914 and a fair rating station was already in operation.

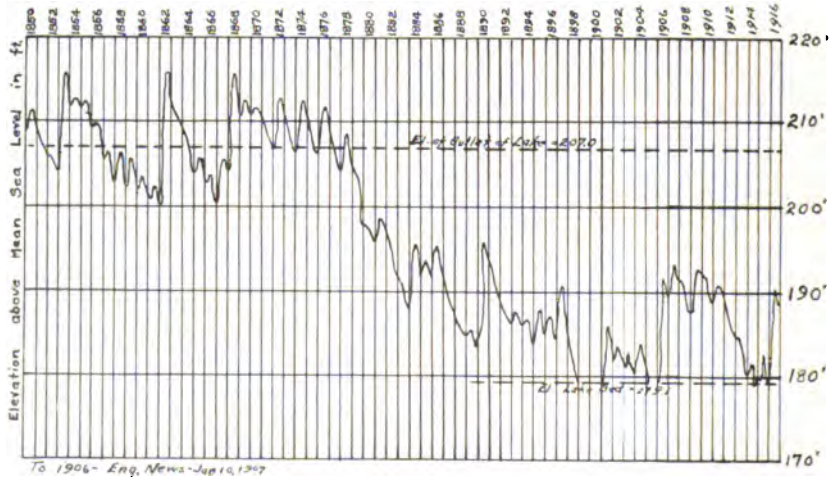
Description of Tulare Lake.

Geographic. Tulare Lake is a broad, shallow basin occupying the lowest depression of Tulare basin. It lies in Kings County about 30 miles south of Fresno and 40 miles northwest of Bakersfield. The lake bed resembles a large flat saucer, the lowest point of which is 179.1 feet above sea level. A map has been prepared from public and private data showing the topography of the lake bottom.

Hydrographic Data. Tulare Lake is fed by the waters of four of the principal rivers south of the San Joaquin River, viz: the south branch of Kings River,

PLATE X.





FLUCTUATIONS IN DEPTH OF TULARE LAKE, 1850 TO 1916.

Kaweah River, Tule River and Kern River. Kaweah River reaches the lake through the various branches of Cross Creek, Cameron, and Packwood creeks and Elk Bayou, The excess over diversions of Kern River is ordinarily stored in Buena Vista Lake, but in seasons of exceptional flow surplus water from Buena Vista Lake is discharged into Tulare Lake through Buena Vista Slough. Kaweah and Tule rivers are the only streams wholly tributary to the lake. In former times Kings River contributed all or nearly all of its flood flow to the lake, but in recent years its course has been so altered by artificial means as to send most of its flood waters to the San Joaquin River through Fresno Slough. Interests owning lands along Fresno Slough have changed the course of the river so that they might obtain irrigation water during the summer months. While this work has been beneficial so far as flood conditions in Tulare Lake are concerned, it has also been detrimental to those lands lying on the southern slope of the Kings River delta in that it has greatly reduced the amount of water available for the irrigation of those lands.

Kern River rarely has sent any water to Tulare Lake in recent years. It is said that for 25 years previous to 1906 no water from Kern River entered Tulare Lake. In that year Kern River water reached the lake in the latter part of June and continued to flow until late in the summer. In 1916 the flow from Kern River reached the lake about January 31, 1916, and continued until after August 1st, following.

The depth of the lake has fluctuated between dry and about 37 feet. The following data is taken from the map of San Joaquin Valley, 1886, by Wm. Ham. Hall and describes the fluctuations of the lake surface from 1852 to 1886:

Fluctuations of the Lake's Surface.

"High water of 1852 is known to have been as great as that of 1862. At low water of 1861 the surface stood about 204 feet above low tide in Suisun Bay. At high water 1862, it rose to 220 feet. Thence it receded to about 206 or 207 feet. High water of 1868 the surface was at 219.6 feet. Low water of 1871, 210.7. High water of 1873, 216.6.

From 1873 to 1883 the waters gradually receded with 2 to 4 feet annual fluctuations to the low water of 1883, which was 192 feet—the lowest known.

From 1883 there has been a gradual rising, with annual fluctuations, until at high water of 1886 it was about 200 feet above the reference plane.

The extreme fluctuation known is, hence, about 28 feet.

The area at highest water (elevation 220 feet) was 760 square miles.

The area at lowest water (elevation 192 feet) was 195 square miles.

The area at time of Creighton Survey, 1880 (elevation 208 feet), was 445 square miles."

The reference plane of Wm. Ham. Hall's map was the old State of California Datum and is about four feet below the United States Geological Survey datum used on the map accompanying this report.

Summarizing the fluctuations of the lake level and reducing them to mean sea level we have the following:

Year	Wm. Ham. Hall elevation	Mean sea level elevation	Depth	Area, square miles
1852	220	216	36.9	760
1861	204	200	20.9	----------
1862	220	216	36.9	----------
1867	206-207	202-203	22.9-23.9	----------
1868	219.6	215.6	36.5	----------
1871	210.7	206.7	27.6	----------
1873	216.6	212.7	33.6	----------
1880	208	204	24.9	445
1883	192	188	8.9	195

A record of the fluctuations of the lake surface from 1906 to date is shown in Plate I. This record was compiled from United States Geological Survey reports. Plate II shows the fluctuations from 1850 to 1916.

1916 Flood.

History. The heavy rains of January, 1916, caused flood stages in all streams of the state and particularly high stages in those streams at the southern end of the San Joaquin Valley. On January 17th, Kings River reached an instantaneous maximum flow of 45,000 cubic feet per second, with a mean daily flow of 28,500 second-feet. Kaweah River discharged 9,600 second-feet on the same date, while on the 18th Kern River had a mean discharge of 16,100 second-feet. Later in the month these streams were again at flood stages and high rates of flow were maintained during February and March. The heavy discharges during April, May and June exceeded those of the earlier months, being augmented by the melting snows.

The first water of the season was from Kings River and reached the lake on January 20th. Kaweah River and Tule River waters reached the lake immediately afterward, while overflow from Buena Vista Lake reached Tulare Lake about February 1st.

In November, 1915, the flooded area in the bottom of the lake amounted to only 6.6 square miles, none of which was included in so-called reclaimed territory.

With the rise of the water successive reclamation levees were overwhelmed. Breaks occurred with each high wind until by midsummer but two districts remained intact, El Rico Land Company and G. A. Smith Reclamation District, with the western part of the Lovelace District barely holding against the water. About October 1st the Smith District levees failed, leaving only El Rico and part of the Lovelace District out of water. Of all the reclamations in the bottom of the lake these two survived and they only by incessant vigilance and tremendous effort.

The dates breaks occurred and areas flooded thereby are as follows:

January 26, 1916—	
12 sections T. 21 S., R. 20 E.	
9½ sections T. 22 S., R. 21 E.	
Reclaimed land flooded	13,720 acres
February 25th—	
7 sections T. 21 S., R. 19–20 E.	
Reclaimed land flooded	4,480 acres
March 5th—	
Goldberg & Barbour District.	
6 sections T. 21 S., R. 20 E.	
Reclaimed land flooded	3,840 acres
April 2d—	
Lewis Reclamation District.	
T. 21 S., R. 21 E.	
Reclaimed land flooded	14,000 acres
May 23d—	
Part of Lovelace Reclamation.	
T. 21 S., R. 21 E.	
Reclaimed land flooded	2,370 acres
October—	
G. A. Smith Reclamation.	
T. 21 S., R. 19–20 E.	
Area flooded	1,920 acres
Total reclaimed land flooded, 1916	40,330 acres

From the map above referred to studies of the storage, or holding capacity, of the lake at different depths has been made.

The map below the 190-foot contour is based on Neilson's map of Tulare Lake bed, and above that line is based on Wm. Ham. Hall's map of the San Joaquin

Valley, 1886. Contours on the west side of Buena Vista Slough are based on elevations determined by a survey conducted by the Kings County Development Company.

Two gages on Tulare Lake were established by the State Department of Engineering. Both were located on the property of El Rico Land Company, one known as the "Point" gage being located at the northwest corner of section 3, T. 22 S., R. 21 E., and the other known as the "Headquarters" gage was located on the north line of section 2, of the same township and range and in the Tule River canal. The elevations of the zeros of these gages was practically 180.0 feet. Both gages were read until the "Point" gage became submerged. The records were carefully kept and promptly reported by the officials of El Rico Land Company.

Tables of capacity of the lake for various flood conditions were compiled, as follows:

Capacity of Tulare Lake.
Natural Ground—No Reclamations.
Capacity of Unreclaimed Land—Tulare Lake.
Capacity of Reclaimed Land—Tulare Lake.
Capacity Table—Tulare Lake—Jan. 26–Feb. 25.
Capacity Table—Tulare Lake—Feb. 25–March 5.
Capacity Table—Tulare Lake—March 5–April 2.
Capacity Table—Tulare Lake—April 2–May 23.
Capacity Table—Tulare Lake—After May 23.

TABLE No. 1.

Capacity of Tulare Lake—Natural Ground; no Reclamations.

Contour	Area under contour, square miles	[1]Volume between contours, square-mile-feet	Capacity up to contours, square-mile-feet	Capacity up to contour, acre-feet
180	35.40		14.15	9,050
		47.24		
181	59.08		61.39	39,300
		70.76		
182	82.45		132.15	84,500
		91.28		
183	100.12		223.43	143,000
		108.60		
184	117.08		332.03	212,500
		126.44		
185	135.81		458.47	293,500
		143.86		
186	151.92		602.33	391,000
		161.67		
187	171.42		764.00	489,000
		180.32		
188	189.21		944.32	605,000
		198.77		
189	208.33		1,143.09	732,000
		220.58		
190	232.83		1,363.67	873,000
		238.64		
191	244.44		1,602.31	1,026,500

[1]A square-mile-foot is one square mile covered one foot in depth and is equivalent to 640 acre-feet.

TABLE No. 2.

Capacity of Unreclaimed Land Tulare Lake, Use for Flood Conditions up to January 26, 1916.

Contour	Area under contour, square miles	Volume between contours, square-mile-feet	Capacity up to contours, square-mile feet	Capacity up to contour, acre-feet
180	14.64		4.39	2,810
		20.64		
181	26.65		25.03	16,050
		32.74		
182	38.83		57.77	37,000
		42.98		
183	47.12		100.75	64,500
		51.76		
184	56.40		152.51	97,600
		60.37		
185	64.34		212.88	136,400
		67.74		
186	71.15		280.62	180,000
		74.53		
187	77.91		355.15	227,500
		79.98		
188	82.06		435.13	279,000
		84.32		
189	86.57		519.45	332,500
		90.14		
190	93.70		609.59	390,000

TABLE No. 3.

Capacity of Reclaimed Land, Tulare Lake.

Contour	Area under contour, square miles	Volume between contours, square-mile-feet	Capacity up to contours, square-mile-feet	Capacity up to contour, acre-feet
180	20.76		9.76	6,250
181	32.48	26.60	36.36	23,200
182	43.62	38.02	74.38	47,800
183	52.95	48.28	122.66	78,400
184	60.68	56.82	179.48	115,000
185	71.47	66.08	245.56	157,000
186	80.77	76.12	321.68	206,000
187	93.51	87.14	408.82	261,500
188	107.15	100.33	509.15	326,000
189	121.76	114.46	623.61	399,000
190	139.13	130.44	754.05	482,000

TABLE No. 4.

Capacity of Tulare Lake, January 26, 1916, to February 25, 1916.

Contour	Area under contour, square miles	Volume between contours, square-mile-feet	Capacity up to contours, square-mile-feet	Capacity up to contour, acre-feet
180	27.44		10.98	70,000
181	41.05	34.24	45.22	29,000
182	56.91	48.98	94.20	60,000
183	67.44	62.18	156.38	100,000
184	77.66	72.55	228.93	146,500
185	85.70	81.68	310.61	199,000

TABLE No. 5.

Capacity of Tulare Lake, February 25, 1916, to March 5, 1916.

Contour	Area under contour, square miles	Volume between contours, square-mile-feet	Capacity up to contours, square-mile-feet	Capacity up to contour, acre-feet
180	27.56		11.00	7,000
181	42.20	34.88	45.88	29,400
182	59.54	50.87	96.75	62,000
183	71.19	65.36	162.11	103,800
184	81.41	76.30	238.41	152,700
185	91.40	86.41	324.82	208,000

TABLE No. 6.

Capacity of Tulare Lake, March 5, 1916, to April 2, 1916.

Contour	Area under contour, square miles	Capacity between contours, square-mile-feet	Capacity up to contours, square-mile-feet	Capacity up to contour, acre-feet
180	28.99		11.60	7,300
181	46.90	37.94	49.54	31,700
182	65.39	56.14	105.68	67,600
183	77.20	71.30	176.98	113,200
184	87.42	82.31	259.29	165,900
185	97.41	92.42	351.71	225,000
186	104.66	101.02	452.73	290,000
187	111.90	108.28	561.01	359,000

TABLE No. 7.

Storage Capacity of Tulare Lake at Different Depths, April 2, 1916, to May 23, 1916.

Contour	Area under contour, square miles	Volume between contours, square-mile-feet	Capacity up to contours, square-mile-feet	Capacity up to contour, acre-feet
180	35.40		14.15	9,050
		47.19		
181	58.98		61.34	39,200
		69.70		
182	80.42		131.04	83,800
		87.61		
183	94.80		218.65	140,000
		101.50		
184	108.19		320.15	205,000
		114.12		
185	120.06		434.27	278,000
		124.60		
186	129.15		558.87	357,500
		134.12		
187	139.08		692.99	443,500
		142.66		
188	146.23		835.65	535,000
		149.77		
189	153.31		985.42	631,000
		158.62		
190	163.93		1,144.04	732,500

TABLE No. 8.

Capacity of Tulare Lake after May 23, 1916.

Contour	Area under contour, square miles	Volume between contours, square-mile-feet	Capacity up to contours, square-mile-feet	Capacity up to contour, acre-feet
180	35.40		14.15	9,050
		47.19		
181	58.98		61.31	39,200
		69.88		
182	80.77		131.22	84,000
		88.26		
183	95.74		219.48	140,400
		102.72		
184	109.69		322.20	206,100
		115.88		
185	122.06		438.08	280,200
		126.86		
186	131.65		564.94	361,000
		136.84		
187	142.04		701.78	448,500
		145.82		
188	149.60		847.60	542,000
		153.26		
189	156.92		1,000.86	640,500
		162.28		
190	167.63		1,163.14	744,500
		170.80		
191	173.97		1,333.94	854,000

In addition to the gages maintained by the State Department of Engineering the United States Geological Survey in cooperation with the department maintained its regular gage located on the north line of section 17, T. 21 S., R. 19 E.

The driving effect of the wind on broad, shallow bodies of water is very marked, and after a hard blow the water may be several inches higher on the lee side than on the windward side of the lake, hence the agreement between the two sets of readings taken on opposite sides of the lake is considered very satisfactory.

By reference to these tables the capacity and flooded area of the lake is readily ascertained and is also shown graphically on the accompanying hydrograph.

It will be seen from the hydrograph that the maximum amount of water in the lake proper for the flood conditions of 1916 was approximately 800,000 acre-feet.

Stream Flows.

From the record kept by the United States Geological Survey in cooperation with the Department of Engineering, tables of the daily discharges of the main tributary streams at the base of the foothills have been compiled. These discharges are shown on the accompanying hydrographs of Kings, Kaweah, Tule and Kern rivers. The Tule River shows the combined discharges of North and South Fork as measured at a point about nine miles east of Porterville. The Kern River record was furnished by the Kern County Land Company.

In order to measure the amount of water entering Tulare Lake from each of the above streams gaging stations were established near the lake margin.

On Kings River a station was established in 1914 at the Empire No. 2 Weir near Stratford. The station was rated and gage records kept for parts of the years 1914 and 1915. Careful gage records were kept for the entire flow of 1916.

Kaweah River water reaches Tulare Lake through the various channels of Cross Creek. On the map accompanying this report these channels are noted as East, Middle, and West channels of Cross Creek. Gaging stations were established on each of these channels, but the station records were not good and later in the season they were all affected by backwater from the lake. The contribution of Cross Creek (or Kaweah River) water to the lake has been estimated by comparing discharge measurements made on certain days with the discharge of the main river at Three Rivers for the previous day and applying the same proportion to the average flow of the main river for a considerable period to determine the amount contributed to the lake for the same period.

The Tule River station was located at the county road bridge on the east line of section 12, T. 22 S., R. 22 E. Good gage readings were taken at this station from April 1st to the end of the season. For January, February and March before the gage readings commenced the flow into Tulare Lake was estimated in a manner similar to that used for Kaweah River.

The station on Buena Vista Slough at Hart Station, NW¼ section 6, T. 27 S., R. 22 E., was established to measure the contribution of Kern River waters to Tulare Lake. The record of this station is very good. The gage was read daily from March 23 to July 29, when the water fell below the zero. Flow at this station stopped on August 5th. Several discharge measurements were made at this station and a good rating curve determined. The flow past Hart Station is estimated for the months of January, February and part of March. The estimated and measured quantities contributed by each of the main streams is shown on the hydrograph of that stream.

The following table shows the flow of water reaching Tulare Lake, expressed in acre-feet, for each month:

TABLE No. 9.

Monthly Flow of Water Reaching Tulare Lake in 1916, in Acre-Feet.

Month	Kings	Kaweah	Tule	Kern	Totals
January	23,100	*45,800	*38,300		107,200
February	11,400	*29,000	*34,500	*72,000	146,900
March	26,800	*50,900	*58,100	150,000	285,700
April	19,300	*27,600	4,860	219,100	270,860
May	46,700	*26,000	3,000	234,400	310,100
June	53,900	*22,800	270	162,100	238,970
July	5,050	*10,500		89,800	105,350
August				2,480	2,480
Totals	186,150	212,500	134,030	929,880	1,462,560

*Figures estimated.

The totals in the above table greatly exceed the amount of water in the lake according to the foregoing tables of capacities estimated from the contour maps.

The discrepancy may be accounted for in part in several ways. The contours of the map as stated elsewhere were platted partly from private surveys which have not been verified, and partly from the published maps of the former State Engineering Department. The latter showed only general and not detailed features of topography. It is highly probable that when an accurate contour survey of the lake bottom shall be made much of the discrepancy will be eliminated.

Some of the gage readings were affected by backwater from the lake, and that

influence might have been operating for a longer time than allowed for in the estimates.

Also, in the table of stream flow no allowance is made for evaporation, which would amount to a large factor in the final estimates.

Furthermore, outside of the flooded area of the lake bottom, particularly at the south and east of the lake, was an additional flooded area which had intercepted a portion of the metered water before it could reach the lake. The area thus covered amounted to about 148 square miles and although most of the water temporarily impounded by it reached the lake, in any attempt to account for losses, that flooded area as well as the lake's surface proper must be regarded as evaporation areas.

Seepage into the soils beneath the water would also absorb a considerable portion, but there is no known way to arrive at the quantity it represents, but an approximation may be obtained of the probable evaporation losses.

In the following determinations the evaporation area of the lake at its maximum area for each given month is used both on rising and falling stage. This makes allowance for the extra evaporation from wetted surfaces after recession of the waters and for the evaporation due to the winds driving the water out on the dry ground.

Evaporation rates in the Tulare Lake region are high. Mr. Chas. H. Lee in "The Possibility of Permanent Reclamation of Tulare Lake Basin, California," Engineering News, January 10, 1907, uses evaporation factors based on the experiments of the State Engineering Department at Kingsburg. 1880–1884. Mr. Lee uses factors for Tulare Lake which are the means of evaporation from a pan floating in the river and a pan on the bank. His factors are as follows:

TABLE No. 10.

Evaporation from Tulare Lake.

Month	Evaporation in feet	Month	Evaporation in feet
November	0.175	June	0.630
December	.102	July	.766
January	.074	August	.791
February	.096	September	.578
March	.214	October	.314
April	.250		
May	.416	Total	4.404

The following table exhibits the inflow to Tulare Lake by months, the estimated losses from evaporation both in the lake proper and waters held outside and the accumulated remainder each month:

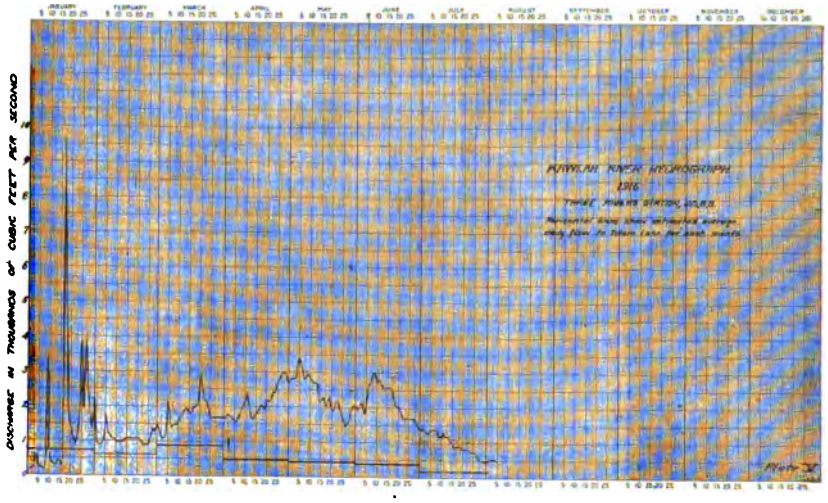
TABLE No. 11.

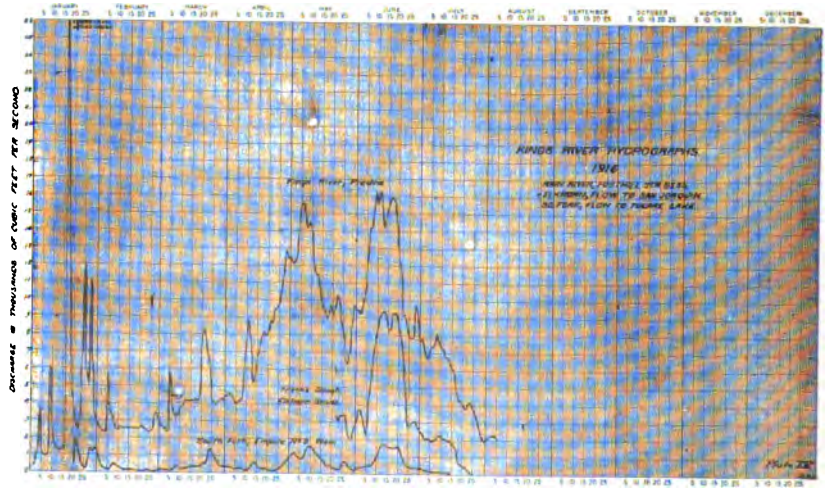
Inflow and Evaporation, Tulare Lake Basin, 1916, Expressed in Acre-Feet.

	January	February	March	April	May	June	July	August	September	Totals
Kern River	----------	72,000	150,000	219,100	234,400	162,100	89,800	2,480	----------	929,880
Tule River	38,300	34,500	58,100	4,860	3,000	270	----------	----------	----------	134,030
Kaweah River	45,800	29,000	50,800	27,600	26,000	22,800	10,500	----------	----------	212,500
Kings River	23,100	11,400	26,800	19,300	46,700	53,800	5,050	----------	----------	186,150
Total monthly accessions	107,200	146,900	280,700	270,860	310,100	238,970	105,350	2,480	----------	1,462,560
Lake area, square miles	60	75	108	143	162	171	171	168	167	
Lake area, acres	38,400	48,000	69,000	91,500	104,000	110,000	110,000	107,000	107,000	
Evaporation rate, inches	.074	.096	.214	.250	.416	.630	.766	.791	.578	
Evaporation[1]	2,800	4,600	14,800	22,900	43,300	69,300	84,200	85,500	61,800	389,200
Overflow, square miles	----------	148	148	148	148	148	148	50	25	
Overflow, acres	----------	95,000	95,000	95,000	95,000	95,000	95,000	32,000	16,000	
Evaporation[2]	----------	9,100	20,300	23,800	39,600	59,300	72,800	25,300	9,200	259,900
Total evaporation[3]	2,800	13,700	35,100	46,700	82,900	129,100	157,000	110,800	71,000	649,100
Net gain or loss	+104,400	+133,200	+245,600	+224,160	+227,200	+109,870	—51,650	—103,320	—71,000	+813,460
Accumulated totals in basin acre-feet	104,400	237,600	483,200	707,360	934,960	1,044,430	992,780	884,460	813,460	
Capacity of lake to surface of water existing on last day of month, acre-feet	76,000	128,000	325,000	490,000	682,000	799,250	755,500	671,500	621,000	
Storage and seepage loss.s in overflow	+28,400	+81,600	+48,600	+58,160	+35,200	—7,380	—7,900	—24,320	—20,500	
Accumulations unaccounted for, acre-feet	28,400	109,600	158,200	217,360	252,560	245,180	237,280	212,960	192,460	

[1]Evaporation from lake surface—acre-feet.
[2]Evaporation from overflow areas south and east of lake—acre-feet.
[3]Total evaporation losses from lake surface and outside waters—acre-feet.
+Indicates storage increase. —Indicates storage decrease—acre-feet.

PLATE XI.


KAWLAR RIVER HYDROGRAPH
1916
THREE RIVERS STATION, U.S.R.S.
DISCHARGE IN THOUSANDS OF CUBIC FEET PER SECOND


KINGS RIVER HYDROGRAPHS
1916
DISCHARGE IN THOUSANDS OF CUBIC FEET PER SECOND

Owing to the lack of definite data as to contour locations south of the sand ridge on the southern margin of the lake proper, it is difficult to make any estimate on the amount of water stored in this basin. The trace of the flood line is shown on the map. In some places there is an apparent crossing of the contours. The flood line was traced out with a fair degree of accuracy. Any discrepancies shown by the contours should be assigned to improper location of the contours.

At the end of September the amount of water unaccounted for after allowing for evaporation as set forth in table above was 192,460 acre-feet. There were still some pools scattered over the flooded area to the south of the lake. The soil in this portion of the basin is somewhat sandy and would absorb considerable water.

On November 1st the ground as far south as Hart Station and for a width of several miles in the trough of the basin was wet, soft and spongy, with here and there large mudholes. Because of these conditions it is not unreasonable to assume that 192,000 acre-feet of water was taken up by the soil.

Comparison of 1906 and 1916 Floods.

From the records of discharges of the streams tributary to Tulare Lake comparative tables have been compiled for the years 1906 and 1916.

The tables are for the period January to July, inclusive, in each case:

TABLE No. 12.

Comparison Table, Floods of 1906 and 1916.
Kings River—Drainage Area, 1,740 Square Miles.

Month	Maximum daily discharge, sec.-ft.	Minimum daily discharge, sec.-ft.	Mean daily discharge, sec.-ft.	Run-off depth, inches per sq. mile	Run-off, acre-feet
1906—					
January	25,500	205	2,360	1.57	144,000
February	2,150	792	1,150	.69	63,900
March	21,000	1,220	5,240	3.47	322,000
April	7,760	2,960	4,720	3.02	281,000
May	16,800	3,930	10,700	7.09	658,000
June	26,600	8,320	17,100	11.00	1,020,000
July	22,400	8,180	16,300	10.80	1,000,000
Total for period					3,488,900
Total for year, October 1, 1905, to September 30, 1906					3,856,700
1916—					
January	*28,480	350	4,530	3.01	279,000
February	5,710	2,340	2,780	1.73	160,000
March	8,400	2,340	4,400	2.93	271,000
April	12,520	3,970	7,580	4.87	451,000
May	15,580	6,340	10,860	7.22	668,000
June	16,340	7,650	12,200	7.83	725,000
July	8,150	1,945	5,340	3.54	328,000
Total for period					2,882,000

Per cent of discharge for same period, 1916, 82.5% of 1906.

Kaweah River—Drainage Area, 520 Square Miles.

1906—					
January	5,760	75	784	1.71	48,200
February	840	274	418	.84	23,200
March	8,160	472	2,440	5.41	150,000
April	2,720	1,460	1,910	4.10	114,000
May	6,840	1,520	3,210	7.11	197,000
June	6,240	2,970	4,670	10.02	278,000
July	5,280	1,340	3,430	7.61	211,000
Total for period					1,021,000
Total for year, October 1, 1905, to September 30, 1906					1,090,000

*Crest 45,000.

TABLE No. 12—Continued.

Kaweah River—Drainage Area, 520 Square Miles—Continued.

Month	Maximum daily discharge, sec.-ft.	Minimum daily discharge, sec.-ft.	Mean daily discharge, sec.-ft.	Run-off depth, inches per sq. mile	Run-off, acre-feet
1916—					
January	9,640	130	1,576	3.56	96,800
February	1,800	895	1,085	2.26	62,500
March	2,980	1,070	1,770	3.92	108,700
April	2,980	1,580	2,130	4.57	126,500
May	3,440	1,470	2,360	5.25	145,300
June	2,980	1,365	2,170	4.66	129,100
July	1,365	490	1,010	2.17	60,100
Total for period					731,000

Per cent discharge for same periods, 1916, 71.5% of 1906.

Tule River—Drainage Area, 266 Square Miles.

1906—					
January	3,500	98	500	2.17	30,700
February	420	182	200	.78	11,100
March	4,530	210	1,370	5.94	84,200
April	1,370	540	772	3.34	45,900
May	2,780	630	1,080	4.68	66,400
June	1,230	680	972	4.08	57,800
July	730	150	362	1.57	22,300
Total for period					318,400
Total for year, October 1, 1905, to September 30, 1906					335,000
1916—					
January	4,980	53	964	4.18	593,000
February	1,380	400	548	2.22	31,500
March	1,660	505	806	3.50	49,600
April	765	505	611	2.55	36,400
May	715	340	508	2.20	31,200
June	370	193	298	1.26	17,800
July	173	53	104	.45	6,400
Total for period					232,200

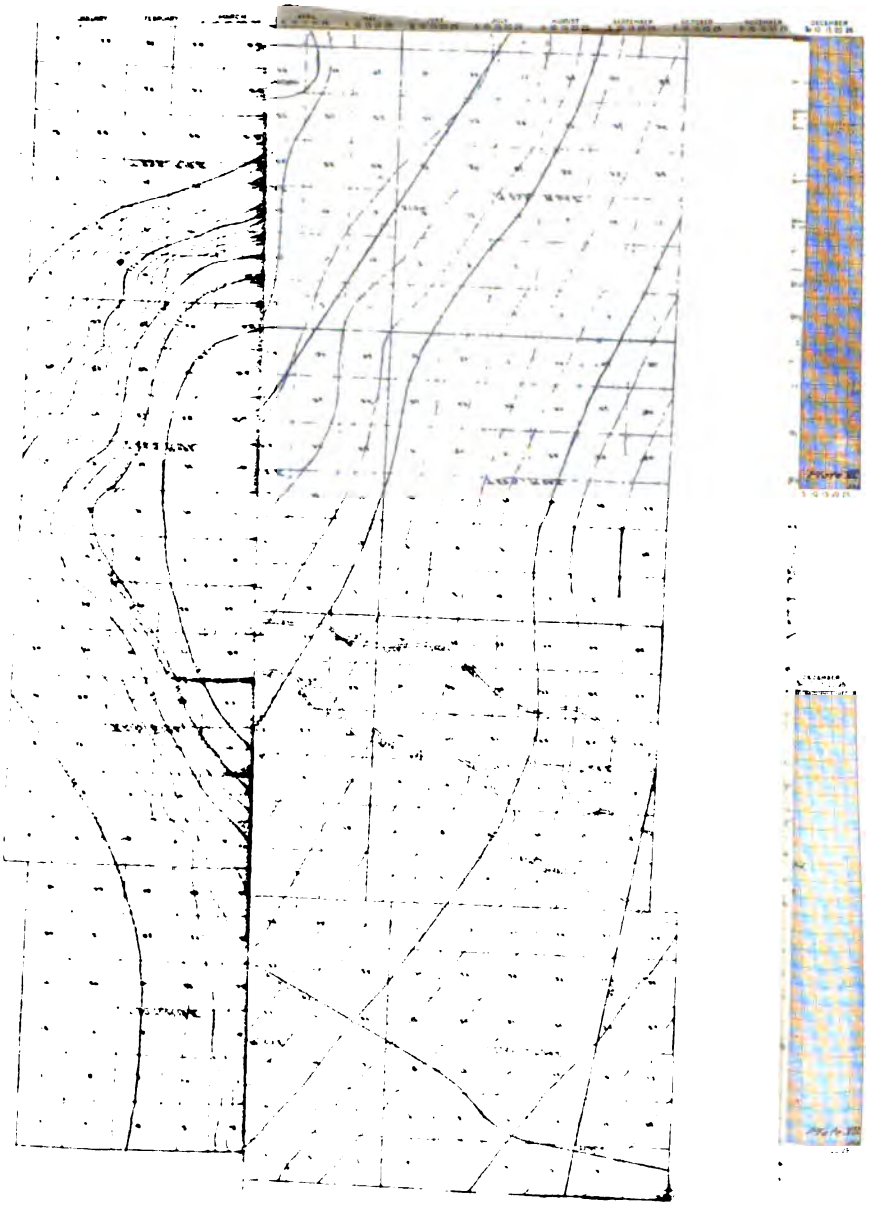
Period percentage, 1916, 73% of 1906.

Kern River—Drainage Area, 2,345 Square Miles.

1906—					
January	2,554	230	693	.34	42,600
February	785	506	626	.28	34,800
March	5,527	755	2,063	1.01	127,000
April	4,255	1,970	2,910	1.38	173,000
May	7,832	2,798	5,859	2.88	360,000
June	9,505	5,306	7,704	3.67	458,000
July	8,431	3,925	6,503	3.19	400,000
Total for period					1,595,400
Total for year, October 1, 1905, to September 30, 1906					1,840,000
1916—					
January	17,960	273	2,803	1.38	172,280
February	5,132	2,602	3,521	1.62	202,470
March	11,830	3,716	6,149	3.00	378,023
April	9,610	7,050	8,096	3.85	481,641
May	9,515	5,865	7,693	3.79	472,886
June	8,139	4,791	6,583	3.13	391,607
July	5,223	1,446	3,662	1.80	225,102
Total for period					2,324,018
Total for year, October 1, 1915, to September 30, 1916					2,463,100

Period percentage, 1916, 146% of 1906.
Year percentage, 1916, 134% of 1906.

PLATE XII.



(p. 56)

TABLE No. 12—Continued.

Kaweah River—Drainage Area, 520 Square Miles—Continued.

Month	Maximum daily discharge, sec.-ft.	Minimum daily discharge, sec.-ft.	Mean daily discharge, sec.-ft.	Run-off depth, inches per sq. mile	Run-off, acre-feet
1916—					
Janu					
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1906—					
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Tot					
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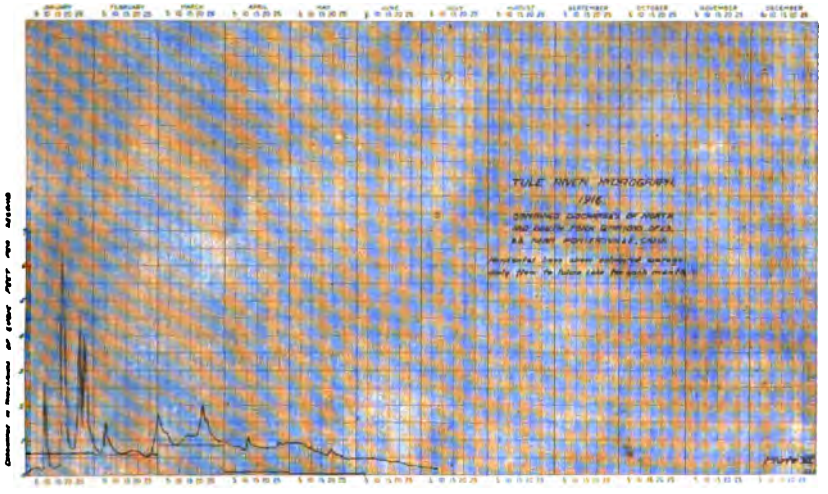
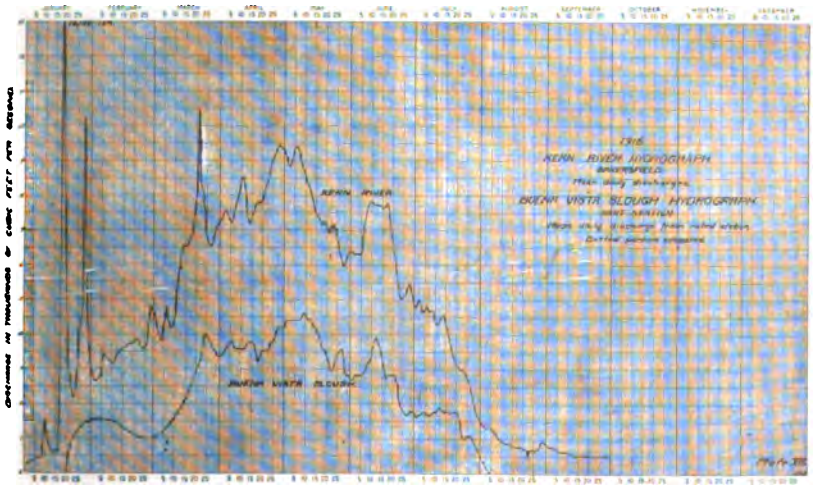
1916—					
Janua					
Febru					
March					
April					
May					
June					
Jul					
October 1, 1915, to 1916					2,463,100

e, 1916, 146% of 1906.
1916, 134% of 1906.

PLATE XII.


TULE RIVER HYDROGRAPH
1916


1916
KERN RIVER HYDROGRAPH
DEEPWATER
DEEP VISTA SLOUGH HYDROGRAPH
KERN RIVER
DEEP VISTA SLOUGH

From the above comparisons it is shown that Kern River was largely responsible for the extended flooding of Tulare Lake in 1916. Its discharge for the period during which it contributed water to the lake was 146 per cent of the same period of 1906, which was the largest amount recorded theretofore. The discharge for the year October 1, 1915, to September 30, 1916, was 134 per cent of the corresponding dates of 1905–6.

In comparing the total discharge of Tule River for 1905–6 with that of 1915–16 the totals for the first period are for the North Fork of Tule River only, the station on South Fork not having been established until 1911. The South Fork in 1916 contributed about 32 per cent as much as the flow of North Fork for the same period, and that ratio has been used in interpolating the figures for the entire stream flow, and the hydrograph shows the combined daily discharges of these streams. The large discharges of Tule River recorded as reaching the lake in January, February and March are due in some measure to additions received from Kakeah River through Elk Bayou, which flows into Tule River east of the gaging station.

In all the above computations of flow for 1916, excepting those for Kern River, which were furnished by the Kern County Land Company, the discharges were determined from gage heights and the latest rating tables of the United States Geological Survey. In most cases these tables were for 1915, hence the figures given are preliminary and are subject to changes, which probably will be very small, when the final records for 1916 are published.

In 1906 Kings River was responsible for the extended flooding of the lake. In 1916 the total amount contributed by this stream was less than any of the others excepting the Tule River. This is accounted for by the increased diversions and the changing of the course of the river as detailed under the description of streams entering the lake.

Acknowledgments. The State Department of Engineering acknowledges indebtedness to the following-named gentlemen for information and assistance in collecting data concerning the flood of 1916:

Mr. Max W. Enderlein, Hanford; Mr. A. D. Schindler, San Francisco; and Capt. A. L. Hunter, Corcoran.

Also the following volunteer gage readers:

Mr. R. J. Davis, Mr. W. H. H. P. Johnson, Mr. Leo van den Enden, all of Corcoran; and Mr. T. J. Hart, Lost Hills.

The department takes this opportunity to express its thanks and appreciation for their interest and substantial assistance in collecting the field data for this report.

CONSERVATION OF NATURAL RESOURCES.

In considering the subject of controlling and conserving the enormous forces under discussion one is confronted with the great costs necessary to erect works to convert them into resources. In this connection it has been suggested that certain natural resources reserved by the national government might well be devoted to this end.

It so happens that nearly all of the streams whose waters present such complex problems of flood control, reclamation, navigation and irrigation, have their sources in the canyons of the high mountains. It also happens that most of the territory drained by these streams and from which their waters come, is covered with great forests of timber, much of which is in National Forest Reserves, being withheld from sale or disposal by the government.

Some statistician has estimated that the forests in these reserves in California contain more than one hundred billion feet of standing timber of merchantable quality. It is also estimated that the value of this timber on a stumpage basis is two dollars for every thousand feet. At that rate the forests of California situated about the headwaters of her turbulent streams, and reserved from exploitation contain a revenue value which would go a long way toward assisting in the construction of reservoirs and other controlling works to direct the destructive forces of the floods to useful purposes.

In this connection it seems pertinent to suggest that now is a proper time for the State to endeavor to enlist the cooperation of the government to the end that the revenues from the National Forest Reserves be devoted to the construction of the works mentioned.

The use of large sums thus obtained which it would seem might rightfully be expended in the region from which the revenues are drawn would enable the State to expend its own funds upon projects outside the forest reserves, the development of which demand all the financial assistance the State has to offer—and more.

The consideration of the foregoing is commended to the people of the State represented in the Legislature.

DEBRIS CONTROL.

In 1893 the congress passed an act known as the "Caminetti Act," authorizing hydraulic mining on the tributaries of the Sacramento and San Joaquin rivers, under prescribed restrictions and created the California Debris Commission to enforce those regulations.

The commission, composed of three officers of the Engineer Corps of the United States Army in addition to its duties of regulating hydraulic mining was enjoined to mature and adopt plans to improve the navigability of the above-named river systems, to protect same from damage due to mining debris, and to afford relief thereto in flood time.

In pursuance of its duty first mentioned, the commission grants license to operate mines by the hydraulic process whenever the operator has provided means for preventing the debris from the mine reaching the navigable streams. Such prevention is usually accomplished by dams creating reservoirs in which the debris can be impounded. Such measures are frequently so expensive that not many mines are being operated under the licenses issued. Since the commission was created and prior to July 31, 1916, it had received 897 petitions for authority to operate, but not all were granted. During 1915 only five applications were made and one license to operate granted.

In complying with the duty imposed upon the commission to devise means of preventing injury to the navigable streams from debris the commission formulated plans for the control of debris in the Yuba River. Congress in 1896 and 1902 appropriated $400,000, and the state a like amount with which the commission has constructed training and controlling works on the Yuba River above Marysville. These works, which have been fully described in previous reports, are showing their utility by a marked decrease in the quantity of debris being carried by that stream into the Feather River.

The problems of navigation and flood control, the solution of which was confined to the Debris Commission, was made the subject of extensive research and study and resulted in 1910 in the presentation of a most comprehensive plan for the accomplishment not only of improved navigable conditions but the complete control of floods and permanent reclamation of the inundated lands of the Sacramento Valley, under the joint effort of the government and the state.

The plan presented is now being executed by the State Reclamation Board and Department of Engineering in cooperation with the United States as more fully discussed herein under the title of "Sacramento River Problems."

The details of the operations conducted by the Debris Commission for the year ending June 30, 1915, appear in the report of the commission herein quoted in full.

EXTRACT FROM THE ANNUAL REPORT OF THE CHIEF OF ENGINEERS TO THE SECRETARY OF WAR.

WAR DEPARTMENT,
OFFICE OF THE CHIEF OF ENGINEERS,
Washington, September 28, 1915.

* * * * * * *

CALIFORNIA DEBRIS COMMISSION.

Jurisdiction and duties extend over the drainage area of the Sacramento and San Joaquin rivers, comprising the great central valley of California and extending from the crest of the Sierra Nevada Mountains on the east to that of the Coast Range on the west; from Mount Shasta on the north to the Tehachapi on the south. These rivers empty into the head of Suisun Bay, ultimately discharging through the connecting bays and straits to the Pacific Ocean through the Golden Gate.

PRELIMINARY GENERAL STATEMENT.

Act of Congress approved March 1, 1893 (27 Stat. L., p. 507), created the California Debris Commission, to consist of three officers of the Corps of Engineers, and prescribes the duties of the commission.

During the fiscal year the commission consisted of Lieutenant Colonel Thomas H. Rees, Corps of Engineers (senior member); Major R. R. Raymond, Corps of Engineers; Major S. A. Cheney, Corps of Engineers (secretary), from July 1 to August 7, 1914, and from that date Major L. H. Rand, Corps of Engineers (secretary), the secretary having immediate supervision of the work.

The duties imposed and powers conferred upon the commission are:

First. To regulate hydraulic mining in such a way as to permit its resumption and continuance as far as the same might be practicable without so unduly interfering with river conditions as to cause injury to other interests in the state.

Second. To study and report upon general hydraulic and hydraulic mining conditions and matters affecting or affected by them, for the purpose of improving the navigability, deepening the channels, and protecting the banks of the rivers and affording relief from flood damages. While the commission was to "adopt" plans as a result of its study, no provision of means for permitting it directly to carry them out was made. Congress has from time to time adopted certain of the plans formulated by the commission, made appropriations therefor, and directed their execution, under the direction of the Secretary of War and the supervision of the Chief of Engineers. The present duties of the commission, therefore, fall under two heads:

(*a*) Those directly imposed upon it by congress under two subheads above given (pp. 1600–1603).

(*b*) Those assigned to it by the War Department as a logical consequence of its other duties. These latter at present consist of: 1. Treatment of the Yuba River debris situation (p. 1603); 2. Alleviation of debris conditions in the Sacramento and Feather rivers, California (p. 1606).

These four are separately covered under the general arrangement of previous portions of this report.

For the Commission's Own Report Giving Additional Details of Its Work, See Pages 3455 to 3465.

1. Regulation of Hydraulic Mining.

Location. While this is as given above, in practice the operations are largely limited to the territory on the western watershed of the Sierra Nevada Mountains, between Mount Lassen on the north and the Yosemite Valley on the south.

Original Condition. Following the discovery of gold in California and the development of the hydraulic method of working the placer deposits in the mountains and foothills, vast quantities of the material washed out of the banks, denominated "debris," passed down into the lower ground, naturally depositing in the beds of the watercourses and rivers, and at high-water times being carried over the banks of the streams to the adjacent country. The results of this filling of navigable channels, destroying of the fertility of lands, breaking of levees, etc., was that mining by the hydraulic process has been effectively stopped by judicial injunction.

Previous Project. None.

Present Project. As adopted in the organic act above given, contemplated the resumption and continuance of hydraulic mining under the regulation of the commission. This is effected by the issuance, on application and after prescribed information has been furnished and the matter received full consideration, of permits to operate by the hydraulic process those mines for which satisfactory debris-restraining basins, formed by construction of suitable dams where necessary, have been provided.

Operations and Results Prior to the Fiscal Year. The commission had received 899 applications for permits to mine, and granted such of them as it was suitable to do. Hydraulic mining on a very limited scale has been restored without the addition in any considerable amount of new debris to that previously deposited in the rivers, creeks and canyons of mining regions. The navigable streams below have hence been able to progressively work off their overload of debris. Navigation in the upper reaches of the rivers and flood conditions have in consequence been improved. Expenditures for these purposes have not been kept separate from those for studies and reports given below.

Operations and Results During the Fiscal Year. During the year five applications for permits to mine were received, and one was granted. Four permits were revoked because of failure to comply with the rules adopted by the commission. Numerous inspections were made of the hydraulic mining region and of mines and their works for restraining debris. The result has been a reasonable maintenance of the favorable conditions existing. Expenditures have not been kept separate from those for studies and reports given below.

Condition at the End of the Fiscal Year. Ten hydraulic mines are operating under licenses and three others have been authorized to construct impounding works. The improved conditions of navigability which have resulted partly from the general cessation of hydraulic mining have not been impaired by such mining as has been done under permits.

Local Cooperation. An antidebris association, formed and supported by local interests that would be injured by the restoration or increase of former conditions, works along lines of prevention by injunction and criminal prosecution under state laws, as do various other local officials and volunteers. They report from time to time indications of violations of the laws, and in turn seek and are furnished information from this office on the subject.

Effect of Improvement. Can be expressed only in the general terms given above.

Proposed Operations. Consideration will be given applications for permits for hydraulic mining and regulation of those operating under permits, with necessary inspections, preparations and approval of plans, etc., as during preceding years.

Commercial Statistics. The commercial statistics for Sacramento, Feather, Mokelumne and San Joaquin rivers, as separately reported upon elsewhere, are in a degree dependent upon this work. No others relating thereto are or can be at reasonable expense compiled.

2. Studies and Reports Upon General Hydraulic and Hydraulic Mining Conditions and Matter Affecting or Affected by Them.

Present Project. This consists of progressively examining, surveying, studying conditions, maturing plans and reporting upon same, for improving those conditions upon the Sacramento and San Joaquin rivers and their several tributaries affected by hydraulic mining operations.

Operations and Results Prior to the Fiscal Year. Surveys had been made of

those portions of the Feather, Yuba, Bear and American rivers in which there are great deposits of mining debris. Incidental to studies relative to the relief from injuries to navigability and from floods, surveys have also been made of portions of the Sacramento, Mokelumne and San Joaquin rivers and of the interconnecting sloughs in the delta of these three streams. Plans have been prepared and adopted for restraining the debris movement in Yuba River (see No. 3 hereunder) and for alleviating debris conditions from the Sacramento and Feather rivers (see No. 4 hereunder). A report upon a comprehensive flood-control scheme for the Sacramento River and tributaries has been submitted. (See H. Document No. 81, 62d Congress, First Session.)

Expenditures from appropriations for "Expenses of California Debris Commission," including those under No. 1 and No. 2, which can not be separated, aggregate (to June 30, 1914) $234,089.46*

Operations and Results During the Fiscal Year. Survey of the lower Mokelumne River and of the several sloughs connecting it to the Sacramento and San Joaquin rivers has been continued. Examination and surveys of critical points on Sacramento and San Joaquin rivers, for use in maturing plans for improving navigability and for relief from floods, have been made. There were expended from appropriations for "Expenses for California Debris Commission," including those under both No. 1 and No. 2, $14,947.42.

Local Cooperation. No cooperative conditions were imposed by congressional act. The state reclamation board act adopted, with such modifications as might be found necessary, the plan reported upon by the California Debris Commission for flood control on the Sacramento River. The commission cooperates with the state reclamation board to the extent of reviewing all of those plans submitted to the board, which are referred to the commission.

Effect of Improvement. Is as given in the general terms expressed above.

Proposed Operations. Further studies, examinations and surveys will be made along same lines as during previous years.

Commercial Statistics. The commercial statistics for Sacramento, Feather, Mokelumne and San Joaquin rivers, as separately reported upon elsewhere, are in a degree dependent upon this work. No others relating thereto are or can be at reasonable expense compiled.

FINANCIAL SUMMARY.

Amount expended on all projects to June 30, 1915:			
New work			[1]$249,036 88
Maintenance			
Amount expended during fiscal years ending June 30:			
	1913	1914	1915
New work	$9,200 95	[2]$14,193 93	$14,947 42
Maintenance			

APPROPRIATIONS.

(For last five fiscal years only.)

March 4, 1911	$15,000 00
August 24, 1912	15,000 00
June 23, 1913	15,000 00
August 1, 1914	15,000 00
March 3, 1915	15,000 00
July 1, 1914, balance unexpended	[3]$9,721 20

*Approximate; records of office prior to 1906 destroyed by fire.
[1]Approximate only; records of district office prior to 1906 destroyed by fire.
[2]A reduction of 80 cents from figures reported in 1914 report, due to refund from overpayment made in that fiscal year.
[3]This increased 80 cents due to refund of overpayment.

Amount appropriated by sundry civil act approved August 1, 1914		$15,000 00
Amount appropriated by sundry civil act approved March 3, 1915		15,000 00
		$39,721 20
Deduction on account of reversion to United States Treasury:		
June 30, 1914	$3,187 06	
June 30, 1915	5,728 07	8,915 13
		$30,806 07
June 30, 1915, amount expended during fiscal year for works of improvement		[4]$14,947 42
July 1, 1915, balance unexpended		$15,858 65
July 1, 1915, outstanding liabilities		274 88
July 1, 1915, balance available		$15,583 77
Amount (estimated) required for expenses of California Debris Commission during fiscal year ending June 30, 1917		$15,000 00

3. Treatment of the Yuba River Debris Situation—Restraining Barriers.

Location. The works of this project are located on the Yuba River, California, between Marysville and the place where the Yuba River emerges from the foothills near Hammonton, some ten miles easterly from Marysville, and about nine miles below the Narrows.

Original Condition. Before this improvement was begun the mining debris that was being carried down by this stream from the old hydraulic mine workings in the Sierra Nevadas was allowed to pass on into the navigable channels of the Feather and Sacramento rivers. This had resulted in the navigable channels of these streams being seriously impaired, and navigation on them was threatened with cessation.

Previous Projects. None.

Present Project. The present project, in a rather indefinite form, was adopted by the river and harbor act of June 11, 1896, and in its more determinate form, was adopted by the river and harbor act of June 13, 1902, in accordance with report (H. Document No. 431, 56th Congress, First Session). This report contemplated, primarily, the storage of mining debris within the bed of the Yuba River by a system of works designed to separate the coarse material from the fine; and, secondarily, the restriction of the low water channel below these works to narrow, well-defined limits, in order to preserve in place the extensive mining debris deposits already in the river. The objects sought were to be accomplished by (1) the construction of four restraining barriers in the bed of the river to hold back the coarser materials, and a settling basin nearby to catch the finer material carried in suspension, and (2) by the construction below the barriers of training walls to confine the river to well-defined lines. The barriers were to be built by steps, successive steps to be built when the storage basin, formed by the preceding step, had filled with debris. The object of storing this debris in the Yuba River—a nonnavigable stream—was to keep it from passing on into the navigable channels of the Sacramento and Feather rivers, to the detriment of the navigation therein. The estimated cost of the project was $800,000, one-half of which was to be borne by the state of California.

By the river and harbor act of June 25, 1910, the settling basin was eliminated from the project and the sale of the land acquired for its purpose authorized.

Operations and Results Prior to the Fiscal Year. The barriers to be built were numbered, going downstream, respectively, 2, 1, 3, and 4, being serially numbered

[4]Includes $571.16 available only for outstanding liabilities of previous fiscal year; none such known.

in the order that it was at first planned they should be built. The first step of barrier No. 2 was built and some material was placed in barrier No. 1, when both were carried away by floods of November, 1906. Barrier No. 2 was then abandoned. The plans were revised to give a more stable design, and two steps of barrier No. 1, with side wall to separate the spillway from the main dam, and part of spillway were constructed, but this barrier was destroyed by flood in March, 1907. Then barrier No. 1 was abandoned. By this time the recently developed gold-dredging operation procedure had advanced to such a stage that it was practicable in this locality to take advantage of the work the dredges were doing. The dredges in working over ground separate the fine material from the coarse rocks. This, of course, increases the volume and raises the height of the worked-over ground from 15 to 20 feet above its original level. The finer material is deposited below the original ground surface, while cobbles and coarse gravel are left above the natural surface to withstand the action of the water. In this way a training wall or levee of cobbles and coarse gravel, which obviates the need of the two lower barriers proposed, was built. The cut through Daguerre Point (a low promontory extending from the north bank well out into the stream, a cut through which was proposed in conjunction with the lowest restraining barrier) was made and the inlet wall, or spillway, in the same constructed. This cut was necessary to obtain a good foundation for the spillway for the proposed lower barrier. Cobble training walls on each side of the river below this cut were built for some 12,000 feet. The entrance gates to the settling basin were constructed, most of its inclosing levees were built, and the outlet works were practically completed when this part of the project was found no longer necessary and was abandoned under authority of the river and harbor act of June 25, 1910. The land acquired for the settling basin was then sold, together with the intake and outlet works.

The river channel from the lower end of the training walls to Marysville had been cleared of brush and trees at different times. This work was done to enable the high water to get away from the vicinity of the works at a fast rate and to aid the river to cut a deep permanent channel along definite lines.

The result of this work has been that many million cubic yards of mining debris have been held within the bed of the Yuba River that would otherwise have passed on into the navigable channels of the Feather and Sacramento rivers.

The expenditure of this project prior to the fiscal year was $348,328.85 of United States funds, together with an expenditure of $347,678.88 by the state of California. All of this expenditure was for original improvement.

Operations and Results During the Fiscal Year. During the fiscal year the inlet wall at Daguerre Point cut was raised about 18 inches and covered with a wooden deck, the toe of the inlet wall was protected, and the brush and trees were cut away from the river channel just above the inlet wall. Below the training walls an embankment was thrown up across the head of an old channel and two smaller channels leading into it were also closed. The brush and trees were cut from the banks and channel of the three miles of the river immediately above Marysville, and some additions were made to the training wall system below Daguerre Point. The total expenditure of the year was $19,815.48, $9,983.51 of which were expended by the United States and $9,831.97 by the state of California. All the expenditure was for original improvement.

It is estimated that 3,880,000 cubic yards storage capacity was added to the storage basin above by the raising of the inlet wall, and it is thought the wooden deck will better withstand the wear of gravel passing over it than did the concrete surface heretofore afforded. The cutting away and burning of the brush and trees immediately above the inlet wall serves to distribute the attack of the water-borne gravel upon that wall. The embankment across the old channel has cut off what threatened to be a change in the main channel of the river and has maintained in place the debris already stored in that old channel. The clearing away of the brush and trees over the portion of the river just above Marysville is aiding the river toward making its permanent channel.

Condition at the End of Fiscal Year. It is estimated that 91.5 per cent of the project was completed at the end of the fiscal year. The total expenditure up to

that time was $715,823.21, all of which was for original improvement. Of the total expenditure $358,312.36 was from United States funds, and $357,510.85 was expended by the state of California.

Local Cooperation. The act approved June 13, 1902, appropriating the final $250,000 of the $400,000 the United States has appropriated for the project, provided that the state of California should also appropriate $400,000 for the project, to stand half the cost. The state of California has met the conditions imposed by congress. Two gold-dredging companies—the Yuba Consolidated Gold Fields and the Marysville Gold Dredging Company—have built training walls on the south side of the river, below Daguerre Point cut. This has been done in connection with their dredging operations. The Yuba Consolidated Gold Fields has also built a training wall, or rock levee, which has taken the place of the two lower barriers proposed in the original project. It is estimated that it would have cost the United States $450,000 to have built the 22,500 linear feet of training walls.

Effect of Improvement. The retaining of this debris in the bed of the Yuba River has facilitated continuous navigation on the Sacramento River, and during the higher stage of the water, on the Feather River. Conditions on both these rivers in regard to obstructions from debris are steadily improving.

Proposed Operations. As it is thought that the funds available for this improvement are sufficient to cover for several years the cost of the work that will be done, no appropriation is asked for this project.

No especial deterioration, destruction, or decay has taken place to the works of this improvement during the past year.

Commercial Statistics. See commercial statistics for Sacramento River.

FINANCIAL SUMMARY.

Amount expended on all projects to June 30, 1915:			
New work			[1]$358,312 36
Maintenance			
Amount expended during fiscal years ending June 30:			
	1913.	1914.	1915.
New work	$2,014 86	$315 04	$9,983 51
Maintenance			

APPROPRIATIONS.

(For last five fiscal years only.)

None.

July 1, 1914, balance unexpended	$79,950 63
June 30, 1915, amount expended during fiscal year for works of improvement	9,983 51
July 1, 1915, balance unexpended	[2]$69,967 12

4. Alleviation of Debris Conditions in the Sacramento and Feather Rivers, California.

Location. The work being done is from the mouth of the Sacramento River, California, at Collinsville, to Rio Vista, 14 miles above.

Original Condition. The valley of the Sacramento and Feather rivers is generally alluvial formation, having the characteristic elevation of river banks, with depressed basins on each side. Debris resulting from hydraulic mining operations and natural erosion had obstructed the channels of these rivers, had by filling materially raised their beds, and had reduced their capacity. The streams have broken through their banks and overflowed large areas during high floods, increasing the number and extent of bars and shoals in the channels themselves. The presence of these large deposits of debris in the river channels and its variable movement downstream had impaired their navigability.

Previous Projects. None.

[1]In addition $357,510.85 has been expended by state of California.
[2]In addition $42,000 is left of the amount appropriated by the state of California.

Present Project. The construction and 56 months' operation of two hydraulic dredges for removal of deposits from the river system to prevent their impeding navigation. It is purely of a qualitative nature, no quantitative results in depth, width, or locality determination having been established. It is based on matter contained (in accordance with the organic act for the California Debris Commission) in the annual report of that commission for 1907, as printed on pages 2253–2269, annual report for that year. The approved estimate of cost was $800,000, half of which was to be provided by local interests according to recommendation of the commission adopted in the river and harbor act of June 25, 1910. This estimate was exclusive of necessary rights of way for spoil bank, levee, etc., which also were to be supplied by local interests. During the time elapsed between the proposal and the adoption of the project, local conditions had so changed that it has been necessary to increase the original estimate for completion to $1,660,000. Daily tidal fluctuation at the mouth is about six feet and varies upstream according to distance and stage. At Sacramento City, 60 miles above the mouth, maximum daily tide of slightly over one foot at extreme low water has been observed. Annual flow variations of level at the city of Sacramento approximate 17 feet, with occasional variations of 20 feet, and extreme cases up to 26 feet variation within a few years.

Operations and Results Prior to the Fiscal Year. Two 20-inch pipe-line hydraulic dredges, together with the necessary auxiliary plant, were constructed at a cost of $444,156.47. These dredges were placed in operation in July and August, 1913, and prior to the fiscal year had excavated 3,373,045 cubic yards of material from the channel of the Sacramento River between Collinsville and Rio Vista.

Of the material excavated 1,550,000 cubic yards was placed in banks which could be used as parts of levees in Sherman Island, and 1,823,000 cubic yards was wasted. The total amount (none for maintenance) expended prior to July 1, 1914, was $639,554.38.[1]

Operations and Results During the Fiscal Year. The dredging plant has been operated and maintained throughout the year, and has excavated 6,379,529 cubic yards of deposit, which has been placed on Sherman Island at Baker's Point, or wasted elsewhere. A retaining embankment for further spoil deposit for a distance of 18,842 feet upstream from Collinsville, containing 301,472 cubic yards, was constructed by hired bucket dredge. The total amount expended on the work during the fiscal year ending June 30, 1915, was $226,288.80. Of this amount $216,268.58 was for the hydraulic excavation and $10,020.22 for construction of the retaining embankment. This has resulted in lowering the river bed and the enlargement of the channel below Rio Vista for 30,000 feet, including the removal of a portion of the old levee on the north side of the channel.

Condition at End of Fiscal Year. One dredge has now been in operation for 20.4 months, the other for 22.4 months, which is 38 per cent of the 112 months' single-dredge operation contemplated. Up to June 30, 1915, there have been excavated from the Sacramento River 9,752,574 cubic yards of material. Below Rio Vista the channel has been enlarged by a width of 275 feet and a depth of 27 feet for a distance of 12,400 feet, and the old levee (13,400 linear feet), located on the north side of the channel, has been removed. Above Collinsville the channel has been enlarged by an average width of 100 feet and a depth of 27 feet for a distance of 4,800 feet; the west side of the channel has been excavated to a depth of 27 feet and width of 250 feet for a distance of 14,000 feet, and 2,598,735 cubic yards of material have been removed from the east side of the channel and placed on Sherman Island. It is not practicable to claim any definite specific results as solely consequent to this operation, but the general improvement noted in those matters which it was meant to effect is believed to follow at least, in part, therefrom. The total expenditure on the project up to June 30, 1915, has been $865,843.18, none of which is for maintenance.

Local Cooperation. Requirements were set out above under "Present Project." The necessary approval of compliance with these conditions as a condition precedent to starting field operations was given by the Secretary of War in 1913. The $400,000

[1]Figures in report for fiscal year 1914 reduced $7.58, owing to refund of overpayment included therein.

was deposited for federal expenditure. It is understood local interests subscribed $260,000, aided by the state and the city of Sacramento, in procuring the land and easements for spoil banks, etc., which they have transferred to the United States. The state has further deposited $200,000 to match equivalent funds made available by the federal government.

Effect of Improvement. Not definite; see above under results.

Proposed Operations. Are to continue the dredging as outlined above under the project exposition. The estimated cost of these operations is as follows: For the operation and maintenance of two hydraulic pipe-line dredges in accordance with the provisions of the act of congress approved June 25, 1910, for a period of 34.6 months from June 30, 1915, at $23,000 per month, $795,800. The amount available on June 30, 1915, from all sources is (in round numbers) $335,000, leaving $461,000 to be provided at this end, of which it is expected one-half will be provided by the state of California or other local agency.

Commercial Statistics. See commercial statistics for Sacramento River.

FINANCIAL SUMMARY.

United States Funds.

Amount expended on all projects to June 30, 1915:			
New work			$460,000
Maintenance			
Amount expended during fiscal year ending June 30:	1913.	1914.	1915.
New work	$268,276 18	$1 67	$60,000
Maintenance			

APPROPRIATIONS.

(For last five fiscal years only.)

October 2, 1914	$60,000 00
March 4, 1915	140,000 00
Amount allotted from river and harbor act approved October 2, 1914	$60,000 00
Amount allotted from river and harbor act approved March 4, 1915	140,000 00
	$200,000 00
June 30, 1915, amount expended during fiscal year, for works of improvement	$60,000 00
	$140,000 00
Amount (estimated) required to be appropriated for completion of existing project	[1]$230,500 00
Amount that can be profitably expended in fiscal year ending June 30, 1917, for works of improvement	[1]75,000 00

FUNDS CONTRIBUTED BY STATE OF CALIFORNIA.

Amount expended on all projects to June 30, 1915:			
New work			[2]$405,843 18
Maintenance			
Amount expended during fiscal year ending June 30:	1913.	1914.	1915.
New work	$17,490 93	[2]$222,063 45	$166,288 80
Maintenance			

APPROPRIATIONS.

(For last five fiscal years only.)

July 1, 1911	$400,000 00
May 20, 1915	60,000 00
July 24, 1915	140,000 00

[1]Exclusive of the balance unexpended July 1, 1915.
[2]Amount reported last year reduced $7.58, due to refund of overpayment made in that year.

July 1, 1914, balance unexpended		[3]$161,208 26
May 20 and July 24, 1915, amount contributed by state of California		200,000 00
		$361,203 26
June 30, 1915, amount expended during fiscal year, for works of improvement		166,288 80
July 1, 1915, balance unexpended		$194,914 46
July 1, 1915, outstanding liabilities	$20,081 65	
July 1, 1915, amount covered by uncompleted contracts	4,695 00	
		24,776 65
July 1, 1915, balance available		$170,137 81
Amount (estimated) required to be appropriated by state of California for completion of existing project		[4]$230,500 00
Amount that can be profitably expended in fiscal year ending June 30, 1917, for works of improvement		[4]75,000 00

CONSOLIDATED.

Amount expended on all projects to June 30, 1915:			
New work			[5]$865,843 18
Maintenance			
Amount expended during fiscal year ending June 30:			
New work	$285,767 11	[5]$222,065 12	$226,288 80
Maintenance			

APPROPRIATIONS.

(For the last five fiscal years only.)

July 1, 1911	$400,000 00
October 2, 1914	60,000 00
March 4, 1915	140,000 00
May 20, 1915	60,000 00
July 24, 1915	140,000 00
July 1, 1914, balance unexpended	$161,203 26
Amount allotted from river and harbor act approved October 2, 1914	60,000 00
Amount allotted from river and harbor act approved March 4, 1915	140,000 00
May 20 and July 24, 1915, amount contributed by State of California	200,000 00
	$561,203 26
June 30, 1915, amount expended during fiscal year, for works of improvement	226,288 80
July 1, 1915, balance unexpended	$334,914 46
July 1, 1915, outstanding liabilities	$20,081 65
July 1, 1915, amount covered by uncompleted contract	4,695 00
	24,776 65
July 1, 1915, balance available	$310,137 81
Amount (estimated) required to be appropriated for completion of existing project	[6]$461,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1917, for works of improvement	[6]150,000 00

[3]This amount is increased 37 cents over that report in 1914, due to refundment of overpayment of that amount.
[4]Exclusive of the balance unexpended July 1, 1915.
[5]Amount reported last year reduced $7.58 due to refund of overpayment made in that year.
[6]Exclusive of the balance unexpended July 1, 1915.

REPORT OF CALIFORNIA DEBRIS COMMISSION.

IMPROVEMENTS.

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For description of improvements in this district, see pages 1599 to 1610.

1. Regulation of Hydraulic Mining.

During the fiscal year five applications for permits to mine by hydraulic process were received. One permit was granted. Four permits were revoked because of failure to comply with the rules adopted by the commission.

SYNOPSIS OF APPLICATIONS TO MINE BY THE HYDRAULIC PROCESS AND ACTION TAKEN THEREON.

Number	Name of mine	County	Name of owner	Mine drains into tributary of	Nature of restraining works	Approximate amount of gravel to be worked	Date of application	Action on application
892	St. Louis	Yuba	F. J. Donohue, J. H. Thomas.	Sacramento River	Concrete dam proposed		Sept. 13, 1912	Authorized to build dam Oct. 23, 1912, construction work not yet begun.
899	Bessie Bench	Shasta	J. G. Andree	Sacramento River	Long crib dam constructed	32,000	April 30, 1914	Authorized to mine March 19, 1915.
900	Brandy City	Sierra	E. L. Goldstein Co.	Sacramento River	Concrete dam proposed	10,000,000	Mar. 22, 1915	Authorized to build dam May 5, 1915.
901	Jaynes Mine	Yuba	R. V. Buckley	Sacramento River	Earth dyke proposed	20,000	Aug. 20, 1914	Authorized to construct dyke Sept. 22, 1914.
902	President Harrison	Plumas	C. A. Macomber	Sacramento River	Reinforced concrete dam proposed.	12,000	Aug. 24, 1914	Action postponed.
903	Waloupa	Nevada	George Wight	Sacramento River	Hydraulic fill proposed	2,000,000	Nov. 7, 1914	Disapproved Dec. 1, 1914.
904	Esperance	Nevada	Phillip Hayes & Co.	Sacramento River	Log dam proposed	39,000	Dec. 7, 1914	Disapproved.

LICENSES REVOKED.

No.	Name of mine	County	Name of owner	Mine drains into tributary of	License revoked
777	Quarry	Tuolumne	Pacific Lime and Plaster Co.	San Joaquin River	May 5, 1915
856	Cleveland	Sierra	Neocene Placer Mining Co.	Sacramento River	Sept. 17, 1914
883	Nigger Gulch	Tuolumne	E. C. Grant	San Joaquin River	Sept. 21, 1914
891	Bear River Hill and Queen City.	Placer	A. W. Nicholls	Sacramento River	Oct. 15, 1914

Ten hydraulic mines are operating under licenses and three others have been authorized to construct impounding works.

Synopsis of Licenses to Mine by the Hydraulic Process in Force June 30, 1915.

No.	Name of mine	Name of owner	Mine drains into tributary of	Kind of dam	Date of license
127	Depot Hill	F. J. Joubert	Sacramento	Concrete	Jan. 5, 1909
768	Brandy City	A. Steinberger	Sacramento	Hydraulic fill	Nov. 30, 1908
837	Sky High	G. W. Bradon et al	Sacramento	Log and brush	Dec. 29, 1908
867	Hydraulic King	Gold Mountain Hydraulic and Dredging Co.	Sacramento	Concrete	Sept. 29, 1913
868	Red Cloud	Alvah G. Eckel	San Joaquin	Hydraulic fill	Oct. 6, 1910
884	Goggens	Sierra Nevada Development Co.	Sacramento	Log	Nov. 21, 1911
885	Cherokee	D. L. Vintin	Sacramento	Concrete and earth	Oct. 21, 1911
897	Birdseye Creek	E. T. Banning et al	Sacramento	Earth	May 26, 1913
898	Omega	South Yuba Mining Development Co.	Sacramento	Cobbles in wire baskets backed by earth fill.	Mar. 13, 1914
899	Bessie Bench	J. G. Andree	Sacramento	Log	June 21, 1915

2. Studies and Reports Upon General Hydraulic and Hydraulic Mining Conditions and Matters Affecting or Affected by Them.

For the purpose of maturing plans for improving navigability of the rivers of the Sacramento and San Joaquin River systems, deepening their channels and protecting their banks with a view to making them effective as against encroachment of and damage from debris resulting from mining operations, natural erosion, or other causes, as called for in the act creating the California Debris Commission, there were made during the fiscal year surveys of Mokelumne River, including both the north and south fork from New Hope Landing to its mouth, Snodgrass Slough from the Mokelumne River to its head in Sacramento Basin, and Georgiana Slough, which connects the Sacramento River at Walnut Grove with the Mokelumne River, near the mouth of the latter, aggregating 49¼ miles in length, and some assistance was rendered the third San Francisco district in a survey of the San Joaquin River proceeding under it, the data for which will be available for commission purposes.

Under state laws all plans for new reclamation of lands from floods and for constructing new or altering old levees within the areas subject to floods of the Sacramento and San Joaquin rivers and their tributaries are submitted to and passed upon by a state reclamation board. All applications and plans for these works are referred by that board to this office, which has in each case indicated to the board whether or not the proposed plans are likely to interfere with carrying out the plans matured and adopted by the commission under the act approved March 1, 1893 (H. Document, No. 81, 62d Congress, First Session).

The expenditures during the fiscal year ending June 30, 1915, for regulating hydraulic mining and making examination and surveys for improvement of naviga-

tion, control and disposition of mine debris and control of flood waters, were as follows:

Regulating hydraulic mining, examinations, surveys, plans for control disposition of mine debris and control of flood waters	$10,592 84
Survey of portions of Mokelumne River, Snodgrass and Georgiana sloughs	4,119 67

APPROPRIATIONS.

Act—	
Oct. 1, 1888	[1]$10,000 00
Mar. 1, 1893 (California Debris Commission)	15,000 00
June 11, 1896 (sundry civil)	15,000 00
June 4, 1897 (sundry civil)	15,000 00
June 19, 1897 (urgent deficiency) (claims)	[2]111 70
July 1, 1898 (sundry civil)	15,000 00
June 7, 1898 (urgent deficiency) (claims)	[2]40
Mar. 3, 1899 (sundry civil)	15,000 00
June 6, 1900 (sundry civil)	15,000 00
Mar. 3, 1901 (urgent deficiency) (claims)	[2]4 37
Mar. 3, 1901 (sundry civil)	15,000 00
Feb. 14, 1902 (urgent deficiency) (claims)	[2]1 52
June 28, 1902 (sundry civil)	15,000 00
Mar. 3, 1903 (sundry civil)	15,000 00
April 28, 1904 (sundry civil)	15,000 00
Mar. 3, 1905 (sundry civil)	15,000 00
June 30, 1906 (urgent deficiency)	[3]5,000 00
June 30, 1906 (sundry civil)	15,000 00
Mar. 4, 1907 (sundry civil)	15,000 00
May 27, 1908 (sundry civil)	15,000 00
Mar. 4, 1909 (sundry civil)	15,000 00
Feb. 25, 1910 (urgent deficiency) (claims)	[2]6 10
June 25, 1910 (sundry civil)	15,000 00
Mar. 4, 1911 (sundry civil)	15,000 00
Aug. 24, 1912 (sundry civil)	15,000 00
June 23, 1913 (sundry civil)	15,000 00
Aug. 1, 1914 (sundry civil)	15,000 00
Mar. 3, 1915 (sundry civil)	15,000 00
Total	[4]$330,124 09
Less reversions to treasury subsequent to 1906	14,081 63
Balance	[4]$316,042 46

CONTRACTS IN FORCE.

Survey Operations on Mokelumne River, California. Lease of Gasoline Launch.

Name of contractor: O. F. Peterson.
Date of contract: August 1, 1914.
Date of approval: Lease; approval not required.
Date fixed for commencement: August 1, 1914.
Actual date of commencement: August 1, 1914.
Date fixed for completion: October 31, 1914.
Percentage of completion at end of fiscal year: 100.
Amount of contract: $600.
Price per unit: $200 per month.

Name of contractor: O. F. Peterson.
Date of contract: December 1, 1914.
Date of approval: Lease; approval not required.

[1] For preliminary examination.
[2] Not disbursed through War Department.
[3] To restore property and records destroyed by fire in April, 1906.
[4] Owing to the destruction in the fire of 1906 of the records of the San Francisco office, where the only accessible record of reversions to treasury, etc., was kept, it is not practicable to reconcile this amount with the amounts indicated in the financial summary, since the reports submitted prior to that time did not so separate these items as to permit their correct entry under present form of obtaining balance.

Date fixed for commencement: December 1, 1914.
Actual date of commencement: December 1, 1914.
Date fixed for completion: February 15, 1915.
Percentage of completion at end of fiscal year: 100.
Amount of contract: $500.
Price per unit: $200 per month.

Commercial Statistics.

See commercial statistics for Sacramento, San Joaquin and Mokelumne rivers.

3. Treatment of the Yuba River Debris Situation.

Restraining Barriers.

Work at Daguerre Point Cut. During the year the inlet wall at Daguerre Point Cut was raised about 18 inches and covered with a wooden deck and the abutment at the north end of the wall was raised about two feet in height by an earth embankment. The end of this embankment and the sides for some distance back were protected by stone paving. This work was done by contract at a total cost of $10,969.28[1] including inspection expenses, one-half of the expenditure being borne by the state of California.

The toe along the northerly 250 feet of the inlet wall showed signs of becoming undermined by the action of the water at flood tide and was therefore protected in the following manner: Concrete was mixed on the deck of the inlet wall and placed in sacks; after the concrete had thoroughly set the sacks of concrete were lowered into place along the toe of the wall, 4,500 sacks of concrete (containing about 450 cubic yards) being placed in this manner. This work was done under an "additional-labor" proviso of the contract just mentioned. The cost of this work, including inspection expenses, was $2,870.65[1], one-half of which was borne by the state of California.

The brush and trees from the channel immediately above the inlet wall were cut down and burned. This was done to distribute the attack of the water-borne gravel upon the inlet wall. About 25 acres of land were cleared in this way at a total cost of $536.54, one-half of which was borne by the state of California. This work was done under the "additional-labor" feature of the same contract.

Embankment Across Old Channel. Below the training walls an embankment was thrown up across the head of an old channel that threatened to take the flow of the river away from the main channel. The lower reaches of this channel contain a quantity of debris which would gradually pass on down the river were it allowed to become the main channel. This embankment serves as a continuation of the training-wall system. Two smaller channels leading into this old channel were also closed. These embankments contained, in all, approximately 13,000 cubic yards of material, and the total cost of this work, including inspection, expenses, grubbing site, brushing completed embankments, etc., was $4,351.32, one-half of it being borne by the state of California. The cost of throwing up the embankment was $3,892.50, or about 29.9 cents per cubic yard. These embankments were constructed with four-mule teams and scrapers, the teams and scrapers being furnished on an oral agreement at the rate of $7.50 per day for four-mule team with scraper and driver.

Brush Cutting from Channel and Banks. The brush and trees were cut from the channel and banks of the Yuba River for the three miles immediately above Marysville. This was done to concentrate the flood flow effects and thus to aid the river in deepening and rendering permanent its channel through this section and to facilitate high-water escape. The banks were cleared for 50 feet to 100 feet back, and the channel cleared of trees and brush that had lodged in it. This work was done by day labor at a total cost of $887.75, one-half of this amount being borne by the state of California.

Additions to Training Walls. The training walls, or rock levees, which are being built by gold-dredging companies, along the lines desired by the United States for furthering the project ends, were extended during the year. About 3,400 linear feet

[1]The total work done under this contract amounted to $13,839.93, from which amount the sum of $53.15 was deducted on account of expenses incurred after expiration of time limit of contract.

of training walls were built above Daguerre Point and about 2,300 feet below Daguerre Point. These training walls are being thrown up by the gold dredges. The gold dredges separate the coarse material from the fine and deposit the coarse on top. This furnishes a rock levee with only large cobbles above the natural surface, while the finer material is left beneath the original surface.

APPROPRIATIONS.

June 3, 1896	[1]$250,000 00
June 13, 1902	[2]150,000 00
Total	$400,000 00
Received from sales	28,279 48
Grand total	$428,279 48

CONTRACTS IN FORCE.

Raising and Covering with Wooden Deck the Inlet Wall at Daguerre Point Cut, Yuba River.[3]

Name of contractor: Nelson & Bauer.
Date of contract: July 17, 1914.
Date of approval: Emergency contract; approval not required.
Date fixed for commencement: July 27, 1914.
Actual date of commencement: July 27, 1914.
Percentage of completion at end of fiscal year: 100.
Amount of contract: $13,317.72.
Prices per unit:

Article	Unit	Unit prices
Pine timber	M foot b m.	$31 60
Steel channels	Linear foot	94
Anchor bolts	100 pieces	88 00
Lag screws	100 pieces	6 54
Lag screws	100 pieces	4 65
Wrought washers	100 pieces	39
Wrought washers	100 pieces	22
Concrete	Cubic yard	8 80
Embankment	Cubic yard	50
Slope paving	Square yard	2 00

COMMERCIAL STATISTICS.

See report on Sacramento River.

4. Alleviation of Debris Conditions in the Sacramento and Feather Rivers.

The operations during the fiscal year have been as follows:

The two 20-inch pipe line hydraulic suction dredges *Sacramento* and *San Joaquin*, together with the necessary auxiliary plant, have been operated and maintained for a period of 10.95 months, the latter having been laid up for repairs from September 2 to October 24, 1914, and the former from December 23, 1914, to January 4, 1915; a hired clamshell-bucket dredge was operated from January 14 to May 22, 1915, and constructed a retaining embankment for spoil deposit.

During the year 6,379,529 cubic yards of material have been excavated from the Sacramento River between Collinsville and Rio Vista and placed as the core of a levee on Sherman Island at Baker's Point or wasted on other spoil banks, at a total cost of $246,370.45[4], or 3.8618 cents per cubic yard.

The dredge *Sacramento* removed 3,585,093 cubic yards of material from the river at a total cost of $107,759.55, or 3.00574 cents per cubic yard; 1,249,352 cubic yards of this was placed as part of a proposed levee on Sherman Island at a cost of

[1]State of California appropriated $250,000 for use with this appropriation at equal rate of expenditure.
[2]State of California appropriated $150,000 for use with this appropriation at equal rate of expenditure.
[3]One-half of cost payable by state of California.
[4]Includes outstanding liabilities.

$53,936.10[1], or 4.31711 cents per cubic yard; and 2,335,741 cubic yards was wasted on spoil banks on the right side of the river at a cost of $53,823.46, or 2.30432 cents per cubic yard.

The dredge *San Joaquin* removed 2,794,436 cubic yards of material from the river, all of which was placed on spoil banks on the right side of the river at a cost of $102,444.84, or 3.66602 cents per cubic yard.

The portion of the levee constructed on Sherman Island at Baker's Point is approximately 6,100 feet in length, 20 feet high, 10 feet wide at the crest and 400 feet at the base, and contains 1,453,965 cubic yards of material, the cost of which has been $93,296.96, or 6.417 cents per cubic yard.

The retaining embankment for spoil deposit constructed by a hired bucket dredge is 18,842 feet long, 6 feet high, and contains 301,472 cubic yards, the cost of which has been $10,020.22, or 3.3237 cents per cubic yard.

The original estimated cost of this project (Rept., June 30, 1907) was $800,000. The report was adopted by congress, June 25, 1910, but during the period between its proposal and adoption reclamation had so increased the value of lands that would have been necessary for spoil banks on the upper rivers, where it had originally been in mind that the dredging would be done, and so concentrated the channel flow to assist in moving deposits downstream, that the cost of doing the work in the upper river would have been increased and the advantages decreased; work was consequently concentrated at the lower end of the river to afford a steeper gradient to the river bottom and a reservoir capacity to absorb the material whose movement downstream was to be thus accelerated. This required digging to a greater depth than was formerly in mind and this in turn, together with the greater exposure to the plant, required larger and more expensive dredges and appurtenant plant than had been included in the figures of the original estimate.

The actual cost, including the cost of the dredging plant, to June 30, 1915, amounts to $885,924.81[2], $444,253.30 of which covered original cost of dredging plant, and $441,671.51[3] have been for maintenance and operation for a mean period of 21.4 months or 38.2 per cent of the operations contemplated in the project, or at a cost of $20,608.45 per month.

As the dredging plant becomes older, maintenance and necessary replacements will require increased expenditure each month, and for the remaining balance of 34.6 months it is estimated that the cost of maintenance and operation of the dredges and appurtenant plant will be $23,000 per month, or $795,800.

APPROPRIATIONS.

By the United States.

Act—	
June 25, 1910	*$400,000 00
October 2, 1914 (allotted Oct. 9, 1914)	†60,000 00
March 4, 1915 (allotted May 27, 1914)	†140,000 00
Total	$600,000 00

By the State of California.

State of California appropriated March 1, 1909, for use with this appropriation, and deposited the amount in the United States Treasury July 1, 1911	*$400,000 00
This amount and any further similar funds contributed were accepted and reappropriated by the cited act of congress.	
State of California appropriated June 7, 1913	†200,000 00
Of which $60,000 was deposited to credit of the United States on May 20, 1915, and $140,000 on July 9, 1915.	
Total	$600,000 00

[1]In addition $22,377.03 was expended in connection with trestle construction for proposed levee.
[2]Includes $22,377.03 expended in connection with trestle construction for proposed levee.
[3]Includes $20,081.65 outstanding liabilities.

Received From Miscellaneous Sources.

For the credit of this appropriation there was received from miscellaneous sources $757 64

Grand total $1,200,757 64

CONTRACTS IN FORCE.

For Fuel Oil and Distillate.

Name of contractor: Standard Oil Co.
Date of contract: August 1, 1913.
Date of approval: Emergency contract; not approved.
Date fixed for commencement: August 10, 1913.
Actual date of commencement: August 5, 1913.
Date fixed for completion: Distillate July 31, 1914; fuel oil July 31, 1915.
Percentage of completion at end of fiscal year: 96.
Amount of contract: Indeterminate.
Prices per unit: Fuel oil, $1.05, 95 cents, 80 cents, and 85 cents per barrel; distillate, 6½ cents and 7½ cents per gallon; according to place of delivery.

Lease of Oil Barge.

Name of contractor: A. K. Varney.
Date of contract: May 11, 1914.
Date of approval: Lease; approval not required.
Date fixed for commencement: May 11, 1914.
Actual date of commencement: May 11, 1914.
Date fixed for completion: September 11, 1914.
Percentage of completion at end of fiscal year: 100.
Amount of contract: $300.
Price per unit, $2.50 per day.

Lease of Launch and Barge.

Name of contractor: Charles H. Ehlert.
Date of contract: July 15, 1914.
Date of approval: Lease; approval not required.
Date fixed for commencement: July 15, 1914.
Actual date of commencement: July 15, 1914.
Date fixed for completion: January 14, 1915.
Percentage of completion at end of fiscal year: 100.
Amount of contract: $1,200.
Price, per unit: $135 per month for launch and $65 per month for barge.

Lease of Launch.

Name of contractor: Charles H. Ehlert.
Date of contract: July 15, 1914.
Date of approval: Lease; approval not required.
Date fixed for commencement: July 15, 1914.
Actual date of commencement: July 15, 1914.
Date fixed for completion: October 14, 1914.
Percentage of completion at end of fiscal year: 100.
Amount of contract: $300.
Price, per unit: $100 per month.

Furnishing Rubber Dredger Sleeves.

Name of contractor: Bowers Rubber Works.
Date of contract: August 18, 1914.
Date of approval: Emergency contract, not approved.
Date fixed for commencement: August 28, 1914.
Actual date of commencement: September 20, 1914.
Date fixed for completion: October 17, 1914.

Percentage of completion at end of fiscal year: 100.
Amount of contract: $4,488.
Price per unit: $44.88.

Lease of Barge.

Name of contractor: Charles H. Ehlert.
Date of contract: October 1, 1914.
Date of approval: Lease; approval not required.
Date fixed for commencement: October 1, 1914.
Actual date of commencement: October 1, 1914.
Date fixed for completion: March 31, 1915.
Percentage of completion at end of fiscal year: 100.
Amount of contract: $390.
Price, per unit: $65 per month.

Lease of Launch.

Name of contractor: Charles H. Ehlert.
Date of contract: October 15, 1914.
Date of approval: Lease; approval not required.
Date fixed for commencement: October 15, 1914.
Actual date of commencement: October 15, 1914.
Date fixed for completion: June 30, 1915.
Percentage of completion at end of fiscal year: 100.
Amount of contract: $850.
Price, per unit: $100 per month.

Lease of Oil Barge.

Name of contractor: Oakland Launch and Tugboat Co.
Date of contract: December 11, 1914.
Date of approval: Lease; approval not required.
Date fixed for commencement: December 17, 1914.
Actual date of commencement: December 17, 1914.
Date fixed for completion: June 16, 1915.
Percentage of completion at end of fiscal year: 100.
Amount of contract: $600.
Price, per unit: $100 per month.

Lease of Gasoline Launch.

Name of contractor: Oakland Launch and Tugboat Co.
Date of contract: January 2, 1915.
Date of approval: Lease; approval not required.
Date fixed for commencement: January 11, 1915.
Actual date of commencement: January 11, 1915.
Date fixed for completion: June 30, 1915.
Percentage of completion at end of fiscal year: 100.
Amount of contract: $765.
Price, per unit: $135 per month.

Lease of Bucket Dredge.

Name of contractor: Suisun Dredging Co.
Date of contract: January 9, 1915.
Date of approval: Lease; approval not required.
Date fixed for commencement: January 14, 1915.
Actual date of commencement: January 14, 1915.
Date fixed for completion: May 29, 1915.
Percentage of completion at end of fiscal year: 100.
Amount of contract: $12,500.
Price, per unit: $110 per day.

Lease of Barge.

Name of contractor: Oakland Launch and Tugboat Co.
Date of contract: March 29, 1915.
Date of approval: Lease; approval not required.
Date fixed for commencement: April 1, 1915.
Actual date of commencement: April 1, 1915.
Date fixed for completion: September 30, 1915.
Percentage of completion at end of fiscal year: 50.
Amount of contract: $390.
Price, per unit: $65 per month.

Commercial Statistics.

See report on Sacramento River, California.

EXTRACT FROM THE ANNUAL REPORT OF THE CHIEF OF ENGINEERS TO THE SECRETARY OF WAR.

WAR DEPARTMENT,
OFFICE OF CHIEF OF ENGINEERS,
Washington, September 28, 1915.

Sacramento-Feather Rivers Board.

This board has charge of the improvement of the Sacramento and Feather rivers, which drain the northern portion of the central valley of California. The exact line of demarcation between the Sacramento and San Joaquin rivers is not determinable with definiteness since, with their common delta, they merge into one another, but the line of the Cosumnes River furnishes as good a boundary as any and is generally assumed therefor. For more detailed description of the limits in other directions, see page 1461 for corresponding description of the third San Francisco, California, district.

The river and harbor act, approved June 3, 1896, required the Secretary of War to appoint the Sacramento-Feather River Board, and provided that the same should consist of three engineers of the United States Army. During the year this board consisted of Lieut. Col. Thos. H. Rees, Corps of Engineers (senior member); Maj. R. R. Raymond, Corps of Engineers; Maj. L. H. Rand, Corps of Engineers (recorder), since August 7, 1914; and Maj. S. A. Cheney, Corps of Engineers (recorder), prior to that date. The recorder exercises immediate supervision over the work.

Improvements.

1. Sacramento and Feather rivers, California (general improvement), page 1457. For board's report, see pages 3345 to 3348, inclusive.

1. Improving Sacramento and Feather rivers, California (general improvement).

Location. The Sacramento River rises in the Trinity Mountains, in northern California, flows about 375 miles in a southerly direction and empties into Suisun Bay. It is navigable from Red Bluff to its mouth, a distance of 261 miles, and this is the portion under improvement. The Feather River heads on the crest of the Sierra Nevadas, flows in a southwesterly course and empties into the Sacramento River about 20 miles (by river) above Sacramento. The lower 30 miles from Marysville to its mouth is navigable. (See U. S. Geological Survey, "Topographic Map of the Sacramento Valley, California.")

Original Condition. Before improvement, navigation on the Sacramento River above Colusa, 150 miles above the mouth, was very difficult on account of snags and bars, and in 1875 it was navigated regularly only as far as Jacinto, 186 miles above the mouth, although it had been navigated regularly to Red Bluff, 261 miles above the mouth, before that time. Below Sacramento there was said to be less than seven feet of water on shoals, and river steamers were unable to reach Sacramento without lightening their cargoes. Feather River was practically unnavigable at low-water stage on account of deposits of mining debris.

Previous Projects. The original project adopted by river and harbor act of March 3, 1875, was modified by river and harbor acts of August 7, 1882, Decem-

ber 21, 1889, July 13, 1892, and amended by river and harbor act of August 18, 1894. The amount expended on all projects prior to the adoption of the present project was $740,860.21. For scope of previous projects, see Appendix, page 1985.

Present Project. Sacramento River is being improved under plans adopted as follows:

Below Sacramento, with a view to securing a least channel depth of seven feet by means of a system of wing dams at or near shoals, supplemented by dredging, if necessary, at an estimated cost of $280,000, adopted by the river and harbor act approved March 3, 1899, in accordance with the reports printed in House Document No. 186, Fifty-fifth Congress, second session, and House Document No. 48, Fifty-fifth Congress, third session.

Above Sacramento, with a view to securing a channel four feet deep up to Colusa, three feet deep from Colusa to Chico Landing, and such depth as is practicable from Chico Landing to Red Bluff, at an estimated annual expenditure of $25,000, adopted by the river and harbor act, approved July 25, 1912, in accordance with the report printed in House Document No. 76, Sixty-second Congress, first session.

The tidal range is six feet at the mouth of the river, and during extreme low water about one foot at Sacramento, at which latter point irregular flow conditions cause a variation of about 20 feet in levels. The distance from the mouth to Sacramento is 60 miles, to Colusa 150 miles, to Chico Landing 201 miles, and to Red Bluff 261 miles. In the report printed in House Document No. 48, Fifty-fifth Congress, third session, a board of engineers expressed the opinion that no permanent improvement of the Feather River could be carried out at reasonable or justifiable cost until the flow of sand and other mining detritus had been stopped. Since the adoption of this report in 1899 no work has been done for the improvement of Feather River.

Operations and Results Prior to Fiscal Year. Prior to the fiscal year snagging had been done annually on the upper and lower Sacramento River; temporary wing dams built and occasional dredging done on the upper Sacramento River; more permanent wing dams built and repairing done to the same, and occasional dredging resorted to on the lower Sacramento River. Snagging had been done and temporary wing dams had been built at various times on the Feather River. Since 1902 the project depths had been maintained on the Sacramento River, except at a few places for a few days, pending restoration work, during low-water periods. The dangers to navigation, especially above Colusa, due to snags and other obstructions, had been greatly reduced, and conditions in the lower regions, due to obstructions of mining debris, had been greatly alleviated. Prior to the beginning of the fiscal year, $363,318.13 had been spent on the present project, of which $37,212.71 was considered to be for original work, and $326,105.42 for maintenance.

Operations and Results During the Fiscal Year. The Sacramento River was snagged from its mouth to Chico Landing, a distance of about 201 miles. Some 1,888 snags were removed from the river and destroyed, and 491 overhanging trees were cut from the banks. This work was done at a cost of $17,561.69. Four new wing dams were built, and 17 wing dams were repaired, at a cost of $8,857.38. Work on a bank protective group of piling at Collins Eddy, Sacramento River, was done at a cost of $2,144.44. All the above work was done with hired labor and with government plant. Dredging was resorted to in two places in the Sacramento River—Sacramento Bend and opposite Knox's lumber wharf at Sacramento. At Sacramento Bend a channel 200 feet wide and 1,000 feet long was dredged to a depth of nine feet at a cost of $1,354.12. Opposite Knox's lumber wharf, a channel 125 feet wide and 600 feet long was dredged to a depth of nine feet, at a cost of $519.87. This dredging was done by a dredge hired at the rate of $135 per day of 22 hours. The project depths on the Sacramento River were maintained during the year, except for a few days at one point. All the work done during the year was for maintenance, and the total expenditures were $33,354.35.

Condition at the End of Fiscal Year. On the Sacramento River, the project depths of seven feet up to Sacramento, four feet up to Colusa, three feet up to Chico Landing, and about two feet from Chico Landing to Red Bluff, are available, and

on the Feather River a depth of about two feet is available. These are the maximum drafts which may be carried over these portions of the rivers at low stages of the rivers.

At the end of the fiscal year $396,672.48 had been expended on the existing project, of which $37,212.71 were for original work and $359,459.77 for maintenance.

Local Cooperation. No local cooperation was imposed by law, but nevertheless it has been quite extensive. The state of California has done extensive bank protection work, built wing dams, made cut-offs, and done various other river work. The cities of Sacramento and Marysville have built municipal wharves and freight sheds, and reclamation districts have dredged much material from the river for levees, to the material aid of navigation. It is estimated that this work has amounted to approximately $3,950,000 on these two rivers.

Proposed Operations. It is proposed to maintain the project depths in the Sacramento River by snagging, building wing dams at shoals and by occasional dredging. The funds, available June 20, 1915, will be exhausted June 30, 1916. The following estimate is submitted:

Above Sacramento:		
Operation of snag boat, six months, at $3,750 per month	$22,500	
Occasional and irregular dredging, estimated at	1,000	
Repairs and additions to wing dams, estimated at	1,500	
		$25,000
Below Sacramento:		
Operations of snag boat, one month, at $3,750 per month	$3,750	
Occasional and irregular dredging, estimated at	3,000	
Building new wing dams, making repairs and adding rock to existing wing dams, estimated at	12,750	
Care of snag boat while idle, five months, at $100 per month	500	
		20,000
Construction of new snag boat, estimated at		60,000
		$105,000

(An estimate is submitted for a new snag boat because the old snag boat is practically worn out and obsolete.)

Commercial Statistics. The commerce on the Sacramento River consists mostly of grain, lumber, fruit, vegetables, and general merchandise. Following is a comparative statement of the amount and value of the commerce for the last three calendar years:

COMPARATIVE STATEMENT.

Calendar year	Short tons	Value
1912	477,292	$27,755,325
1913	733,594	35,856,791
1914	721,000	38,211,760

FINANCIAL SUMMARY.

Amount expended on all projects to June 30, 1915:	
New work	$37,212 71
Maintenance	359,459 71
New work and maintenance	[1]740,860 21
Total	$1,137,532 69
Amount expended during fiscal year ending June 30, 1913:	
New work	
Maintenance	34,078 94

[1]Figures reported last year decreased 80 cents, due to refund of overpayment made in that fiscal year.

Amount expended during fiscal year ending June 30, 1914:	
New work	
Maintenance	[1]$41,544 92
Amount expended during fiscal year ending June 30, 1915:	
New work	
Maintenance	33,354 35

APPROPRIATIONS.

(For last five fiscal years only.)

February 27, 1911	$25,000 00
July 25, 1912	65,000 00
March 4, 1913	40,000 00
March 4, 1915	60,000 00
July 1, 1914, balance unexpended	[2]29,763 73
Amount allotted from river and harbor act approved March 4, 1915	60,000 00
	$89,763 73
June 30, 1915, amount expended during fiscal year, for maintenance of improvement	33,354 35
July 1, 1915, balance unexpended	$56,409 38
July 1, 1915, outstanding liabilities	3,660 04
July 1, 1915, balance available	$52,749 34
Amount that can be profitably expended in fiscal year ending June 30, 1917, for maintenance and improvement	[3]$105,000 00

IMPROVEMENT OF RIVERS AND HARBORS IN THE THIRD SAN FRANCISCO, CALIFORNIA, DISTRICT.

This district embraces the rivers and waterways within the area drained by the Sacramento and San Joaquin rivers, above their confluence at head of Suisun Bay. It is entirely within the state of California and extends from the crest of the Sierra Nevada Mountains on the east to the Coast Range on the west, and from the Cascade Range and the Oregon boundary on the north to the Tehachapi Mountains on the south.

District officer: Major S. A. Cheney, Corps of Engineers, until August 7, 1914, and Major L. H. Rand, Corps of Engineers, since that date.

Division Engineer: Lieutenant Colonel Thos. H. Rees, Corps of Engineers.

Improvements.

Page.
1. San Joaquin River, California ---- 1461
2. Stockton and Mormon Channels (diverting canal), California ---- 1468
3. Mokelumne River, California ---- 1470

For district officer's report giving additional details regarding works in this district, see pages 3349 to 3354.

1. San Joaquin River.

This river is under improvement under several separate projects, the later of which in point of time partially overlap the earlier, and as they become accomplished will supplant the earlier to the corresponding extent. Even, however, where they overlap, the earlier are, pending completion of cooperative requirements for the later, the basis of work. To intelligibly present the subject as a whole the separate projects are carried along seriatim under the usual headings with literal cross references as—

(*a*) Including Stockton and Mormon Channels, maintenance (nine-foot channel).

(*b*) Nine-foot channel and cut-offs.

(*c*) Fremont Channel and McLeod Lake, arms of Stockton Harbor.

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[1]Expended prior to March 3, 1899, before which time records do not indicate expenditures separable into new work or maintenance.

[2]Increased 80 cents due to refund of overpayment.

[3]Exclusive of the balance unexpended July 1, 1915.

Location. (*a*) Its several forks and branches rising in the high Sierras unite to form the San Joaquin River, which then flows southwesterly about 143 miles to Herndon 10 miles northwest of Fresno; thence westerly 48 miles by river to Firebaugh; thence northwesterly 166 miles to mouth of Stockton Channel, 2.5 miles west from Stockton; thence in same general direction 42.5 miles farther to Suisun Bay, thus aggregating about 400 miles in length. Mormon Channel, a branch of Stockton Channel, extends through southerly part of Stockton. Hills Ferry, 87 miles above Stockton Channel, or 129 miles above the mouth of the river, is upper limit of the portion of the river included in the project. In the lower 34 miles of river, there is a governing depth of 15 feet; the only work done in this portion has been the elimination of a large bend by means of a cut-off. The lower 29 miles of channel, though not specifically excluded from the project, is ample to meet all needs of the navigation without any improvement. It should be noted that between the mouth of the river and San Francisco Bay the governing depth of present used navigation channel is about 10 feet, although there is an unmarked channel having a governing depth of 15 feet at mean low water.

(*b*) This project covers San Joaquin River and Stockton channels from the mouth of the former to the head of the latter at the city of Stockton, a distance of 45 miles. These channels are also included under preceding paragraph, and the remarks therein as to lower river conditions apply.

(*c*) Fremont Channel and McLeod Lake, included in this project, form an arm of Stockton Channel, branching off therefrom at a point about 1,500 feet west of El Dorado Street, Stockton, and extend northeasterly about 2,000 feet, all of which is included in the project, forming an important part of the city's harbor. Their distance above the mouth of the river is 45 miles.

Original Condition. (*a*) The lower 34 miles of channel have always been broad and deep. In spite of numerous sharp bends, the 15 miles of channel above, including Stockton Channel, was navigated at low water by boats drawing six feet. The river above Stockton, although obstructed by snags, was navigated by light draft steamboats to Hills Ferry about half the year, and to Firebaugh, 79 miles higher, for a few weeks at high water. At annual high-water periods much silt was deposited in Stockton and Mormon channels and in the river below. Portions of the river flow were diverted through side channels.

(*b*) When this project became operative in 1914, the governing depth was about seven feet. The width between banks was in excess of 200 feet at all except a few reaches near Stockton, where it was as small as 160 to 175 feet.

(*c*) At the time of adoption of the project, the area included therein was generally less than five feet deep at mean low water, a depth insufficient for use by the river boats. (See map in H. Document 581, 62d Congress, second session.)

Previous Projects. (*a*) There was no project for the San Joaquin previous to the adoption of the present existing project.

(*b*) There were two projects prior to the present project, the one for "Improving San Joaquin River, including Stockton and Mormon channels, nine-foot channel, maintenance," and one for "Stockton and Mormon channels (diverting canal)," both of which are still in force and reported on herewith. Prior to 1914, when present project became operative, there had been spent on the first project $641,837.34, and on the second project $245,743.41, a total of $887,580.75. Of the former sum about $60,000 was spent for dredging Mormon Channel, and $29,000 for work in upper river, which are not included in the present project.

(*c*) There was no previous project which included the area under the present project.

Present Project. (*a*) The date of adoption of the present project is taken as August 14, 1876, when the first appropriation for improving the San Joaquin River was made. The project was not based on any printed document, and the records seem to show that the plan of improvement was not well defined at first, but became fairly definite about 1881. The objects to be attained were as follows:

1. To improve certain constricted portions of Stockton Channel and of the San Joaquin River in the three miles just below by dredging to a mean low-water depth of nine feet and a bottom width of 100 feet, all the river below being in excess of these dimensions.

2. To establish and maintain, by dredging, a channel in Mormon Channel from its junction with Stockton Channel up 1.7 miles to Millers Warehouse, Center Street, Stockton, 80 feet wide and four feet deep at low water.
3. To reduce the curvature of the channel by cutting off sharp bends.
4. To make temporary improvements in the low-water channel of the "upper river," above Stockton Channel to Hills Ferry, a distance of 87 miles. The improvements included snagging, removal of overhanging trees and construction of brush wing dams, and were intended to facilitate light-draft steamboat navigation during the high and mean stages of water, it being considered impracticable to maintain a navigable channel during low water.
5. It was additionally provided (river and harbor act of August 11, 1888) to partially close the side channels, Laird's Slough and Paradise Cut, by weirs, and thereby confine their low-water flow to one main channel.

Tidal influence at low water extends about 65 miles above the mouth of the river; its mean range at the mouth is about six feet, and at Stockton about three feet.

Since 1898 the operations under this project have been restricted to maintenance of the river and of Stockton and Mormon channels below Stockton. There is no estimate of available record for annual maintenance.

(*b*) The present project, adopted June 25, 1910 (H. Document 1124, 60th Congress, second session), has for its objects:

1. To improve Stockton Channel and the San Joaquin River by dredging deficient portions to a mean low-water depth of nine feet and to a bottom width of 200 feet, all such deficient sections being within Stockton Channel and the first few miles of river below.
2. To make two cut-offs designated "B" and "C."

The approved estimate of cost of the improvement is $199,632, and of maintenance $25,000, annually.

The length of the San Joaquin River included in the project is 42.5 miles, and of Stockton Channel 2.5 miles.

(*c*) The present project was adopted July 25, 1912, in accordance with House Document No. 581, Sixty-second Congress, second session. Its objects are:

1. To establish, by dredging, a depth of nine feet at mean low water over area included, and
2. To maintain the same.

The estimated cost of "1" was $11,000 and of "2" was $500 annually.

Operations and Results Prior to Fiscal Year. (*a*) The expenditures have resulted in improved channels that have fairly met the needs of commerce. Cost of new work and of maintenance were not kept separate prior to 1898, up to which time the total expenditure *for new work and for maintenance* had been $384,424.58; since then all expenditures have been for maintenance, and have amounted to $257,412.26, making a total expenditure prior to fiscal year since original adoption of project, $641,836.84. (Reduction of 50 cents from figures of 1914 report due to refund of overpayment made in that fiscal year.)

(*b*) There were no operations and no expenditures prior to the fiscal year, as proviso of act adopting project, which required that no part of the funds be expended until titles to right of way required be first conveyed free of cost to the United States, was not complied with until July 8, 1914.

(*c*) The original dredging was completed in March, 1914, at a cost of $11,000, resulting in the approved depth over the entire area. There had been no maintenance operations prior to fiscal year.

(*a*), (*b*) and (*c*). Total expenditures for new work since 1898[1] are $11,000 and for maintenance $257,412.26. Total expenditures for new work and for maintenance since adoption of original project are $652,836.84.

Operations and Results During Fiscal Year. (*a*) Contract was entered into for dredging shoals in the lower portion of Stockton Channel and in the San Joaquin River just below. Under this contract a total of 144,735 cubic yards was removed and pumped ashore. The total expenditure has been $17,331.69, all of which was for maintenance.

(*b*) The cut-off "C" was about nine-tenths completed during fiscal year. The work was done by a leased clam-shell dredging plant. Final payment therefor has not been made. The total amount expended during the fiscal year was $20,411.02, all of which was for new work.

(c) There have been no operations during fiscal year, as none was necessary.

The total expenditures during the fiscal year on all three subdivisions, (a), (b), and (c), was $37,742.71, of which $17,331.69 was for maintenance and $20,411.02 for new work.

Conditions at the End of Fiscal Year. (a) On June 30, 1915, there exists the full project width of 80 feet and mean low water depth of four feet in Mormon Channel, the project width of 100 feet and mean low water depth of nine feet in San Joaquin River and Stockton Channel from the mouth of the former to the head of the latter in city of Stockton, except at a few crossings, where the governing depth is about seven feet. This depth meets requirements of all boats now in use in the river. There is no complete estimate of available record, so that no definite percentage of completion can be stated. At the end of the fiscal year the total expenditures since 1898[1] have been for new work nil and for maintenance $274,743.95, or a total expenditure since original adoption of the project of $659,168.53.

(b) The project is 10 per cent completed and the total expenditures thereunder to end of fiscal year are $20,411.02, all of which were for new work.

The cut-off "C" is now used by all the San Joaquin River traffic. It has the effect of shortening the distance for boats between Stockton and points below, including San Francisco, by about 0.31 mile, of eliminating a bend in the river and also of facilitating the flow of tides, consequently increasing their scour, depended upon to maintain the channel.

(c) No survey of the area has been made recently, but it is believed that there exists the approved depth of nine feet at mean low water over the whole area. The dredged area constitutes a much needed addition to the harbor of Stockton. The total expenditures on this project to end of fiscal year were $11,000, all for new work.

(a), (b), and (c). Since 1898[1] the total expenditures to end of fiscal year have been for new work $31,411.02, and for maintenance $274,743.95, and a total for both new work and maintenance since adoption of original project, $690,579.55.

Local Cooperation. (a) It was required (river and harbor act, July 13, 1892) that right of way for two cut-offs be furnished to the United States free of cost before any part of the appropriation should be expended. This proviso was complied with and the cut-offs made the year following. The following work was done voluntarily by others than the government:

Right of way for Head Reach Cut-off, made in 1891, was furnished by private interests.

Three cut-offs were made by state of California (see Annual Report for 1900, pt. 4, p. 4224).

The city of Stockton formerly maintained a dredge that was used near the city (see Annual Report for 1882, pt. 3, p. 2537), and has built extensive concrete bulkheads and wharves at Stockton.

In March, 1910, San Joaquin County completed the dredging of a shoal in "The Narrows," available government funds having become exhausted.

The dam at Paradise Cut is at present, and for several years past has been, maintained by local interests for purpose of correcting flood conditions.

From 1908 to 1912, before completion of the Stockton and Mormon channels diverting canal, the city of Stockton obtained use of the "Boggs Tract" by lease and diverted the flow of Mormon Slough over it, thereby preventing large deposits of silt in the navigable waters below.

At present there are no cooperative requirements that have not been met.

(b) In compliance with act adopting project, rights of way for cut-offs "B" and "C" were conveyed free of cost to the United States and proceedings are under way to procure the additional lands necessary for widening the river.

(c) It was required in act adopting the project for improvement (p. 9, H. Document No. 581, 62d Congress, second session), that local interests furnish satisfactory evidence to Secretary of War that adequate bulkheads and terminals be provided free of cost to the United States. A statement of status of compliance with this provision was approved by the Secretary of War, September 11, 1912.

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[1]See Operations and results prior to fiscal year (a).

Effect of Improvement. The increased facilities have met the needs of commerce and made possible uninterrupted schedules for water transportation, which have undoubtedly largely decreased transportation costs.

Proposed Operations. (*a*) The funds estimated will be used in supplementing those now available for the necessary dredging and snagging operations. It is probable that the balance available will be expended by January 1, 1917.

(*b*) Funds in hand are adequate to meet all probable expenditure necessary prior to June 30, 1917.

(*c*) With the funds recommended as a profitable expenditure it is proposed to dredge shoals when they shall have formed.

The balance available, $500, is inadequate to justify an operation, and can not be expended advantageously unless supplemented with additional funds, in which case it will probably be expended by June 30, 1917.

Commercial Statistics. The commerce for the calendar year 1914 amounted to 772,156 short tons, valued at $35,479,741, and consisted principally of grain, potatoes, onions, beans, and general merchandise.

COMPARATIVE STATEMENT.

Calendar year	Short tons	Value
1912	632,591	$38,854,589
1913	820,399	38,341,174
1914	772,156	35,479,741

FINANCIAL SUMMARY.

SAN JOAQUIN RIVER, INCLUDING STOCKTON AND MORMON CHANNELS (MAINTENANCE) AND FREMONT CHANNEL AND M'LEOD LAKE.

Amount expended on all projects to June 30, 1915:	
New work	$11,000 00
Maintenance	659,168 53
Total	$670,168 53
Amount expended during fiscal year ending June 30, 1913	3,327 39
New work	175 00
Maintenance	3,152 39
Amount expended during fiscal year ending June 30, 1914	35,118 85
New work	10,825 00
Maintenance	[1]24,293 85
Amount expended during fiscal year ending June 30, 1915	17,331 69
New work	
Maintenance	17,331 69

Reduction of 50 cents[1] from figures of 1914 report, due to refund of overpayment made in that fiscal year.

APPROPRIATIONS.

(For last five fiscal years only.)

Feb. 27, 1911	$25,000 00
July 25, 1912	51,000 00
Mar. 3, 1913	25,500 00
July 1, 1914, balance unexpended	[1]$58,344 41
June 30, 1915, amount expended during fiscal year for maintenance of improvement	17,331 69
July 1, 1915, balance unexpended	$41,012 72
July 1, 1915, outstanding liabilities	272 50
July 1, 1915, balance available	$40,740 22

[1]Increased by 50 cents due to refund of overpayment.

Amount that can be profitably expended in fiscal year ending June 30, 1917, for maintenance of improvement ..... [1]$11,000 00

SAN JOAQUIN RIVER (NINE-FOOT CHANNEL AND CUT-OFF).

Amount expended on all projects to June 30, 1915:

New work	$20,411 02
Maintenance	

Amount expended during fiscal year ending June 30:

	1913	1914	1915
New work			$20,411 02
Maintenance			

APPROPRIATIONS.

(For last five fiscal years only.)

March 4, 1913	$159,632 00
July 1, 1914, balance unexpended	$199,632 00
Deduction on account of transfer under river and harbor act approved March 4, 1915	30,000 00
	$169,632 00
June 30, 1915, amount expended during fiscal year for works of improvement	20,411 02
June 1, 1915, balance unexpended	$149,220 98
July 1, 1915, outstanding liabilities	2,090 33
July 1, 1915, balance available	$147,130 65
Amount (estimated) required to be appropriated for completion of existing project	[1]$30,000 00

CONSOLIDATED.

Amount expended on all projects to June 30, 1915:

New work	$31,411 02
Maintenance	659,168 53
Total	$690,579 55

Amount expended during fiscal year ending June 30:

	1913	1914	1915
New work	$175 00	$10,825 00	$20,411 02
Maintenance	3,152 39	[2]24,293 85	17,331 69
Totals	$3,327 39	$35,118 85	$37,742 71

APPROPRIATIONS.

(For last five fiscal years only.)

Feb. 27, 1911	$25,000 00
July 25, 1912	51,000 00
Mar. 4, 1913	185,132 00
July 1, 1914, balance unexpended	[3]$257,976 41
Deduction on account of transfer under river and harbor act approved March 4, 1915	30,000 00
	$227,976 41

[1]Exclusive of the balance unexpended July 1, 1915.
[2]Reduction of 50 cents from figures of 1914 report, due to refund of overpayment made in that fiscal year.
[3]Increased by 50 cents due to refund of overpayment.

June 30, 1915, amount expended during fiscal year:		
For works of improvement	$20,411 02	
For maintenance of improvement	17,331 69	37,742 71
July 1, 1915, balance unexpended		$190,233 70
July 1, 1915, outstanding liabilities		2,362 83
July 1, 1915, balance available		$187,870 87
Amount (estimated) required to be appropriated for completion of existing project		[1]$30,000 00
Amount that can be profitably expended in fiscal year ending June 30, 1917, for maintenance of improvement		[1]$11,000 00

2. Stockton and Mormon Channels (Diverting Canal).

Location. The Calaveras River separates at Bellota, 14 miles east and six miles north of Stockton. The north channel, still called Calaveras River, flows thence westerly two miles north of Stockton and empties into the San Joaquin River two and one-tenth miles below the mouth of Stockton Channel. The south channel, Mormon Slough, flowed through the southern part of Stockton to Stockton Channel. The length of Stockton Channel is two and five-tenths miles and of Mormon Channel one and seven-tenths miles, a total length of four and two-tenths miles. They extend from 42.5 to 45 miles above the mouth of the river. The extent and location of works for improving these channels is given under "Present Project" below.

Original Condition. The north branch of the Calaveras River, which formerly carried most of the discharge of the stream, had become checked with silt in recent years and Mormon Slough had become the principal branch. During annual freshets there were deposited large quantities of silt in the quiet waters of Mormon and Stockton channels. This necessitated extensive dredging, which constituted nearly two-thirds of all the work done under the project—(*a*) under San Joaquin River. The cost was increasing, due to increasing height of levees and increasing value of land upon which to deposit material dredged.

Previous Projects. There was no project prior to the present one for diverting the flow of Mormon Slough. See the project "For improving San Joaquin River, nine-foot channel, maintenance," page 1461.

Present Project. The object of the present project is to divert the waters of Mormon Slough by means of the works set forth below and thereby prevent their load of debris from being deposited in Stockton and Mormon channels. This project includes the construction of a dam three miles east of Stockton across Mormon Slough, a canal leading thence northwesterly four and sixty-three one-hundredths miles to north branch of Calaveras River, and the enlargement of cross-section of the latter for a distance of five miles to its mouth, at San Joaquin River. The project also includes construction of certain bridges over canal. This project was adopted by river and harbor act of June 13, 1902. It provided that the work be done in accordance with report thereon. (H. Document No. 152, 55th Congress, third session.) The final approved estimate for the work is $280,395. No estimate for annual cost of maintenance was made. The first (and only) appropriation for that purpose was made March 4, 1913, in lump sum for this and two other projects. It was anticipated that the maintenance would consist of repairs to the dam or levee and in clearing the canal of undergrowth.

Operations and Results Prior to Fiscal Year. The works as originally specified were about 85 per cent completed, at a total expenditure of $242,119.52 for new work and $4,048.89 for maintenance, or an aggregate of $246,168.41. The expenditures resulted in the construction of the works as originally specified, except that the amount of channel excavation was about 17 per cent less than specified. From the appropriations for improvement there was expended for maintenance, including repairs to bridges and cutting of thistles along the canal, $3,623.89, most of which was spent prior to June 30, 1911. From the $1,000 appropriated for maintenance

[1]Exclusive of the balance unexpended July 1, 1915.

$425 had been expended prior to fiscal year for exterminating squirrels, destroying thistles, and for administrative work.

Operations and Results During Fiscal Year. The sum of $334.26 was spent during the year for maintenance, $59.26 from original improvement appropriations, and $275 from maintenance appropriation, of which $84.26 was expended for administration and $250 by oral agreement for a particular piece of work, which resulted in keeping down undergrowth along the canal.

Condition at End of Fiscal Year. The project work is about 85 per cent completed, though considerable deterioration has taken place since completion of excavation, due to formation of deposits in the canal bed. The work for the time being prevents formation of most of the silt deposits in Stockton and Mormon channels, thereby saving expensive annual dredging. It is believed that there exist the mean low water governing depths of about eight feet in Stockton Channel and in excess of four feet in Mormon Channel. The total expenditures to end of fiscal year amount to $246,502.67, of which $242,119.52 was for improvement and $4,383.15 was for maintenance.

Local Cooperation. It was required that right of way for canal be furnished the United States free of cost, either by city of Stockton or state of California. This was done by them jointly. Certain work has been done by city of Stockton or San Joaquin County, or both, in maintaining bridges across the canal.

Effect of Improvement. The results expected, in diverting the flow of Mormon Slough, have, to a great extent, been realized, although during flood periods some of the water overflows the south bank above the dam and discharges into Mormon and Stockton channels, thereby causing deposits.

Proposed Operations. With the funds estimated and those on hand, it is proposed to remove deposits and keep down undergrowth in the channel sections so far as the same may seem advisable. The available funds will probably be expended by June 30, 1916.

Commercial Statistics. See report on San Joaquin River, Cal., page 1466.

FINANCIAL SUMMARY.

Amount expended on all projects to June 30, 1915:	
New work	$242,119 52
Maintenance	4,383 15
Total	$246,502 67
Amount expended during fiscal year ending June 30, 1913:	
New work	
Maintenance	1,255 66
Amount expended during fiscal year ending June 30, 1914:	
New work	
Maintenance	425 00
Amount expended during fiscal year ending June 30, 1915:	
New work	
Maintenance	334 26

APPROPRIATIONS.

(For last five fiscal years only.)

March 4, 1913	[1]$1,000 00
July 1, 1914, balance unexpended	$35,234 92
June 30, 1915, amount expended during fiscal year for maintenance of improvement	334 26
July 1, 1915, balance unexpended	$34,900 66
Amount that can be profitably expended in fiscal year ending June 30, 1917, for maintenance of improvement	[2]$10,000 00

[1]Appropriated for "Improving San Joaquin River, California," and allotted for maintenance work.
[2]Exclusive of balance unexpended July 1, 1915.

3. Mokelumne River.

Location. The Mokelumne River rises near the crest of the Sierra Nevadas and flows southwesterly 119 miles to the town of Woodbridge; thence northerly about nine miles to the Galt-New Hope bridge; thence northwesterly, westerly, and southerly eight miles by river to New Hope Landing, where it separates, afterwards reuniting below in a southerly direction nine miles via North Fork and 14 miles via South Fork (forming Staten Island). The river then flows southerly four miles and empties into the San Joaquin 20 miles above the mouth of the latter at Suisun Bay, a total distance of 140 miles via North Fork or 145 miles via South Fork. (See U. S. Geological Survey topographic map, Sacramento Valley scale 1/250,000.) The river lies generally about midway between the cities of Sacramento and Stockton.

Original Conditions. In the lower portion of their courses the two channels are tidal estuaries, tidal action extending to a little above the Galt-New Hope bridge, the head of navigation. All the North Fork was reported to be in good navigable condition, but the South Fork was obstructed by snags and overhanging trees in the 1½ miles just below New Hope Landing. There were also many snags and overhanging trees in portion of rivers between New Hope Landing and Galt-New Hope bridge. A bar was also reported extending across the river at mouth of Cosumnes River. Exact widths and depths prevailing originally are not given. (Annual Report for 1882, pt. 3, pp. 2638 and 2639.)

Previous Projects. None.

Present Projects. The present project was adopted July 5, 1884. It has for its object to maintain a channel suitable to the needs of navigation by means of removal of snags and obstructions and occasional dredging of shoals. The mean low-water depths at present contemplated (considered sufficient for needs of navigation) are as follows:

Location	Depth	Miles
Mouth of river to lower junction North and South Fork	9	4
Lower junction North and South forks to Snodgrass Slough via North Fork	9	8
Snodgrass Slough to upper junction North and South forks	6	1
Lower junction North and South forks to upper junction of same at New Hope Landing via South Fork	9	14
New Hope Landing to Galt-New Hope bridge	8	8

These depths in general prevail, but there is shoaling at New Hope Landing. The mean daily range of tide at low river stages is about three feet. Maximum flood stage at Galt-New Hope bridge is about 17 feet above low water, with annual variation of about 12 feet.

The first estimate made in 1882 of $8,250, which formed a basis for the project, was for clearing the river of all obstructions and improvement of shoals near mouth of Cosumnes River. There is no estimate for annual maintenance of available record.

Operations and Results Prior to Fiscal Year. The work done has consisted largely of removing snags and overhanging trees and of dredging shoals. Of total appropriations of $31,000, $29,902.05 was expended previous to current fiscal year, $21,402.05 of which was for maintenance and $8,500 for new work. The needs of navigation have been fairly met.

Operations and Results During the Fiscal Year. No work has been done on the Mokelumne River during the current fiscal year, none being required. Of the money expended during current year, $243.20, $200 was for administrative work and $43.20 was to cover outstanding liabilities from preceding year.

Conditions at the End of Fiscal Year. No survey has been made since the recent high water, but it is believed that at end of fiscal year there exist the governing depths tabulated above under "Present Project," reference to which is made to avoid extensive repetition here. The channel is believed to be free of obstructions to the head of navigation. Total expenditures to end of fiscal year are $30,145.25.

Local Cooperation. There are no local cooperative requirements of current interest.

Effect of Improvement. The improvements have made possible regular scheduled steamboat operation to the Galt-New Hope bridge. The effect upon transportation costs could be stated only after such extended investigation as is impracticable, but is presumably one of reduction.

Proposed Operations. It is proposed to expend the funds for which estimate is submitted for continuing miscellaneous maintenance operations as need arises, to meet needs of navigation, including dredging, removal of snags, construction of temporary wing dams, etc. The available funds will probably be expended by March 1, 1916.

Commercial Statistics. The commerce for the calendar year 1914 amounted to 69,783 short tons, valued at $3,045,870, and consisted principally of barley, beans, potatoes, vegetables, sheep, canned goods, and general merchandise.

COMPARATIVE STATEMENT.

	Short tons	Valuation
1912	50,443	$2,833,704
1913	90,585	5,079,932
1914	69,783	3,045,870

FINANCIAL SUMMARY.

Amount expended on all projects to June 30, 1915:	
New work	$21,402 05
Maintenance	8,743 20
Total	$30,145 25
Amount expended during fiscal year ending June 30, 1913:	
New work	
Maintenance	710 00
Amount expended during fiscal year ending June 30, 1914:	
New work	
Maintenance	232 40
Amount expended during fiscal year ending June 30, 1915:	
New work	
Maintenance	243 20

APPROPRIATIONS.

(For last five fiscal years only.)

February 27, 1911	$5,000 00
March 4, 1913	1,000 00
July 1, 1914, balance unexpended	$1,097 95
June 30, 1915, amount expended during fiscal year, for maintenance of improvement	243 20
July 1, 1915, balance unexpended	$854 75
Amount that can be profitably expended in fiscal year ending June 30, 1917, for maintenance of improvement	[1]$2,500 00

EXAMINATIONS AND SURVEYS MADE IN COMPLIANCE WITH THE RIVER AND HARBOR ACTS OF FEBRUARY 27, 1911, AND MARCH 4, 1913.

Reports on preliminary examinations and surveys required by the river and harbor acts of February 27, 1911, and March 4, 1913, of the following localities within this district were duly submitted by the district officer. They were reviewed by the Board of Engineers for Rivers and Harbors pursuant to law, and were transmitted to congress and printed in documents as indicated:

[1]Exclusive of the balance unexpended July 1, 1915.

1. *Preliminary examination and survey of Mokelumne River, Cal., with a view to its improvement from the Galt-New Hope bridge to a point at or near Woodbridge.* Reports dated October 16, 1911, and April 2, 1914, with maps, are printed in House Document No. 1160, Sixty-third Congress, second session. The improvement of the locality by the United States in the manner proposed is not deemed advisable at the present time.

2. *Preliminary examination and plan and estimate of cost of improvement of Feather River, Cal., from its mouth to Marysville, with a view to deepening and straightening the channel and to determining what other improvements are necessary in the interests of navigation, consideration being given to any proposition for cooperation on the part of state or other local interests.* Reports dated October 16 and December 29, 1913, are printed in House Document No. 1460, Sixty-third Congress, third session. The improvement of the locality by the United States in the manner proposed is not deemed advisable at the present time, except in so far as already authorized.

The local officer was also charged with the duty of making other preliminary examinations and surveys provided for by the river and harbor acts of February 27, 1911, and March 4, 1915, as follows, and reports thereon will be duly submitted when received:

1. *San Joaquin River, Cal.*, with a view to its improvement up to a point at or near Herndon by means of locks and dams or otherwise.

2. *Sacramento River, Cal., from Chico Landing to Red Bluff.*

REPORT OF SACRAMENTO-FEATHER RIVERS BOARD.

IMPROVEMENTS.

1. Sacramento and Feather Rivers, Cal. (general improvement)..... Page 3345

For description of improvements under this board, see pages 1457 to 1461.

1. Sacramento and Feather Rivers, Cal.

Removal of Obstructions. The Sacramento River was cleared of snags, logs, stumps, and overhanging trees from its mouth to Chico Landing (201 miles). These operations were carried on by the snag boat *Seizer* with a crew of about 32 men. The following is a detailed statement of the obstructions removed in the different portions of the river by the snag boat and crew during the year:

Sections of river	Distance, miles	Logs, trees, stumps and snags blasted or removed from river channel	Overhanging trees and stumps cut from banks	Days operated
Mouth of river to Sacramento	60	43	15	5
Sacramento to Colusa	90	373	69	31
Colusa to Chico Landing	51	1,472	407	120
Totals	201	1,888	491	156

The total field cost of removing these obstructions was $17,561.69.

Wing Dams. Three new wing dams were built on the Sacramento River; one, of a purely temporary nature, 264 feet long, was built about a mile below Chico Landing by the crew of the snag boat *Seizer*, at a cost of $1,525.50; two more of a more permanent nature were built just below Sacramento, one at Sacramento Bend, and one at Merkeleys. These latter were built by hired labor, with government plant, at a cost of $2,100. They were 150 and 200 feet long, respectively.

One wing dam, 105 feet long, was built in the Feather River just above its mouth. This wing dam, however, was built to aid navigation in the Sacramento River by diverting the waters of the Feather River to give a better channel at the confluence of the two rivers. This wing dam was also built by hired labor, with government plant, and at a cost of $1,050. Seventeen wing dams between the mouth of the Feather River and Freeport were repaired at a cost of $4,181.88.

Dredging. Dredging of shoals was resorted to in two places on the Sacramento River at Sacramento Bend below Sacramento and opposite Knox's lumber wharf, a channel 125 feet wide and 600 feet long was dredged to a depth of nine feet, at a cost of $519.87. The dredging was done by a dredge hired at the rate of $135 per day of 22 hours.

Bank Protection Work. A bank protective group of piling about 1,000 feet long, containing 170 piles, was driven at Collins Eddy, Sacramento River. This work was done by hired labor, with government plant, and at a cost of $2,144.44.

Surveys. Surveys of various shoals in Sacramento River were made during July and August, while the river was approaching the low-water stage. These surveys were made to locate accurately the shoals, their extent, and to determine in ample time whether wing dams or dredging would be necessary to maintain the project depths. In some cases surveys were made to determine the effect of the wing dams put in during the previous year. In this way portions of the river were covered by surveys made at the mouth of the Feather River, at Russian Crossing, at Merkeley's Landing, from the mouth of the American to Freeport and at Ida Island. The cost of these surveys and the platting was $952.01.

APPROPRIATIONS.

Previous projects, acts of Mar. 3, 1875, to Aug. 18, 1894, inclusive (see House Document No. 421, 57th Congress, second session, p. 237)		$760,000 00
Present project, act of—		
Mar. 3, 1899	$30,000 00	
June 6, 1900	60,000 00	
June 13, 1902	25,000 00	
April 28, 1904 (allotted May 23 and 31, 1904)	22,000 00	
Mar. 2, 1907	50,000 00	
Mar. 3, 1909 (allotted April 9, 1909)	25,000 00	
June 25, 1910	30,000 00	
Feb. 27, 1911	25,000 00	
July 25, 1912	65,000 00	
Mar. 4, 1913	40,000 00	
Mar. 4, 1915 (allotted April 2, 1915)	60,000 00	
		432,000 00
Total appropriations		$1,192,000 00
Receipts from sales		1,942 07
Total		$1,193,942 07

COMMERCIAL STATISTICS.

The freight and passenger traffic on the Sacramento River is handled by craft which operate on this stream exclusively, and by craft which operate part of the time on other streams (*i. e.*, San Joaquin and Mokelumne rivers), as follows:

VESSEL CLASSIFICATIONS.

Class	Number	Net registered tonnage	Passengers
Registered—			
Steamers	41	18,780	139,816
Gas	49	1,421	34,410
Sailing	37	2,198	----------
Unrigged	45	12,004	----------
Unregistered—			
Steamers	----------	----------	----------
Gas	22	----------	1,259
Sailing	3	----------	----------
Unrigged	13	----------	----------
Totals	210	34,407	175,485

FREIGHT TRAFFIC.

Article	Amount		Short tons	Valuation	Tonnage for which rates and distances are known	Average haul or distance freight was carried (miles)	Rate per ton-mile
	Customary units						
Coal	3,833	tons	3,833	$30,664 00	442	52.7	$0.040
Fuel oil	535,480	barrels	91,082	427,850 40	14,211	53.5	.016
Gasoline	3,970	drums	1,707	78,522 00	205	122.4	.034
Distillate	7,340	drums	3,377	96,244 50	412	72.2	.060
Coal oil	21,630	cases	887	22,175 00	21	100.4	.046
Lubricating oil			151	9,815 00	10	22	.091
Machinery	139	tons	139	20,850 00	133	18.5	.167
Autos	2,147		3,221	2,254,700 00	51	122.7	.057
Wagons	976		976	73,200 00	124	96.8	.097
Buggies	1,000		300	42,000 00	25	150	.033
Sand	52,945	cubic yds.	79,417	52,944 67	50,245	61.3	.013
Gravel	1,598	cubic yds.	2,390	1,598 33	2,380	69.7	.017
Brick	11,976,000		29,930	89,820 00	32	31.1	.009
Cement	24,610	barrels	4,676	46,760 00	3,437	52.3	.045
Crushed rock	2,920	cubic yds.	4,380	4,380 00			
Lumber	33,700	M feet	50,549	505,490 00	3,668	110.5	.046
Piles	11,610		8,707	58,046 60	1,240	119	.013
Shingles	41,573,000		3,118	62,360 00	19	65	.023
Shooks	2,460	M feet	2,460	67,650 00			
Cordwood	3,421	cords	6,842	17,105 00	3,070	40	.046
Wheat	14,102	tons	14,102	943,570 00	6,981	100.7	.015
Barley	63,745	tons	63,745	1,466,135 00	13,010	114.5	.015
Oats	691	tons	691	20,730 00	210	91.4	.023
Corn	23	tons	23	805 00			
Flour	8,010	barrels	801	56,070 00	429	132.5	.017
Millstuff	224	tons	224	6,720 00	224	97.8	.020
Rice	5,065	tons	5,065	405,200 00	204	98.3	.022
Beans	23,348	tons	23,348	1,634,360 00	373	89.3	.103
Potatoes	20,329	tons	20,329	406,580 00	4,028	66.7	.020
Onions	1,582	tons	1,582	15,820 00			
Asparagus	12,001	tons	12,001	600,050 00	4,226	8	.204
Other vegetables	19,900	tons	19,900	995,450 00	2,056	72.7	.080
Hay	30,371	tons	30,371	242,968 00	17,581	75.7	.023
Wool	510	tons	510	183,600 00	25	150	.053
Hides	2,240	bundles	325	162,500 00			
Horses	1,575	head	945	236,250 00	256	38.7	.061
Cattle	2,030	head	710	99,400 00	158	28.9	.024
Sheep	34,224	head	2,139	256,680 00	1,227	65.5	.029
Hogs	13,870	head	1,040	187,200 00	86	69.9	.108
Fruit, fresh	14,109	tons	14,109	987,630 00	3,087	48.8	.057
Fruit, dried	3,591	tons	3,591	538,650 00	295	148.3	.020
Grapes	57	tons	57	1,425 00	57	45	.055
General merchandise	157,954	tons	157,954	19,744,250 00	20,520	126.4	.021
Canned goods	760,600	cases	22,819	2,738,280 00	59	22	.091
Wine	194,500	gallons	940	47,000 00			
Meats	84	tons	84	20,160 00	28	10.7	.418
Fish	2,189	tons	2,189	262,680 00			
Dairy produce	1,164	tons	1,164	232,800 00	198	20	.100
Eggs	1,210	cases	34	10,200 00	1	20	.100
Sugar	2,300	tons	2,300	230,900 00			
Hops	261	tons	261	114,840 00			
Paper	1,487	tons	1,487	148,700 00			
Miscellaneous	16,689	tons	16,689	1,668,900 00	321	180	.086
Asphalt	9,425	barrels	1,366	10,586 50	1,366	96	.013
Poultry			75	22,500 00	56	20	.100
Totals			721,090	$38,211,760 00			

Note.—Attention is invited to the fact that, in general, rates and distances carried are known for short hauls of small lots only, and the rates per ton-mile are therefore necessarily large.

During the spring (1915) a new line of boats began operating upon the Sacramento River. Two gas schooners make a daily trip from San Francisco to Courtland and return, hauling fruit, vegetables and other freight.

Through the Northern Electric Railway drawbridge at M street, Sacramento, 3,054 steamboats, 1,005 barges, 969 gas boats, 73 sailing vessels, 30 dredges and 29 pile drivers passed during the year.

Through the Southern Pacific Railway drawbridge at H street, Sacramento, 895 steamboats, 799 barges, 867 gas boats, 31 sailboats, 27 dredges and 20 pile drivers passed during the year. (Between M and H streets, Sacramento, the project depth changes from seven feet to four feet.)

Through the Southern Pacific Railway drawbridge at Knights Landing, 563 steamboats, 408 barges, 321 gas boats, six sailboats, 8 dredges and seven pile drivers passed during the year.

Through the Northern Electric Railway drawbridge at Meridian 424 steamers, 196 barges, 15 gas boats, two sailboats and nine dredges passed during the year.

In the above only those passages for which draw operation was required are tabulated.

IMPROVEMENT OF RIVERS AND HARBORS IN THE THIRD SAN FRANCISCO, CAL., DISTRICT.

Report of Major L. H. Rand, Corps of Engineers.

IMPROVEMENTS.

		Page
1.	San Joaquin River, Cal.	3349
2.	Stockton and Mormon channels (diverting canal), Cal.	3353
3.	Mokelumne River, Cal.	3353

For description of improvements in this district, see pages 1461 to 1473.

1. San Joaquin River, California.

(A) *San Joaquin River, Including Stockton and Mormon Channels, Nine-foot Channel, Maintenance.*

Contract was entered into July 17, 1914, with Standard American Dredging Company for dredging shoals in Stockton Channel at ten cents per cubic yard and in the San Joaquin River, below its junction with the latter, at nine and nine-tenths cents per cubic yard. (See annual report, 1914, part III, p. 3172.) Operations under this continued from October 1, 1914, to January 8, 1915.

In Stockton Channel, from its junction with Mormon Channel to a point 3,700 feet below, 85,761 cubic yards of material were removed at a price of $8,576.10. Dredging was paid for to a depth of ten feet below mean low water (one foot overdepth), width of bottom 100 feet, and side slopes one and five-tenths feet. The contractor removed material in excess of the required section, in places to a depth of 20 feet below mean low water, in order to use the material for fill on adjacent grounds.

In the San Joaquin River two shoals were dredged, one extending between points 1,600 and 2,500 feet below its junction with Stockton Channel, the other between points 5,000 and 7,000 feet below the junction. A total of 58,974 cubic yards of material was removed at a price of $5,858.43. The section paid for was the same as that in Stockton Channel except that the width was increased at approaches to bends to conform to the natural alignment of river bed.

From the total contract price of $14,414.50, the sum of $39.60 was deducted to cover cost of inspection after time limit.

Administrative charges have brought the total expenditure for fiscal year to $17,331.69.

The material dredged varied from sand to hard clay. It was pumped ashore by the 15-inch suction dredge *Wilmington*, the length of pipe-line varying from 365 to 4,770 feet, average being 2,480 feet.

(B) San Joaquin River, Nine-foot Channel and Cut-offs.

Leases were entered into September 26, 1914, and renewed January 11, 1915, with American Dredging Company for use of the clamshell dredge *Uncle Sam* with an auxiliary plant, for $175 per day of 22 actual working hours, for excavation of cut-off "C," described in House Document No. 1124, Sixtieth Congress, second session.

The dredge operated from October 10, 1914, to February 11, 1915, the estimated amount due the lessor being $19,360.09. In addition to this sum ($19,360), the contractor has presented claim for payment of an additional amount. This claim has been referred to the auditor and final settlement not yet effected. The quantity of material estimated to be removed was 350,000 cubic yards. A survey made in April shows that there has been a total of 320,000 cubic yards removed, leaving 30,000 cubic yards to be removed to complete cut-off.

The banks slipped badly, necessitating rehandling. It was estimated from the operation of dredge that material about 40 per cent in excess of above quantity was handled. The material was sand, loam, peat, and hardpan. The cost per yard on the basis of material actually handled is four and one-tenth cents per cubic yard; on basis of material removed from prism, six cents per cubic yard.

The prism of cut-off as it now exists has the required depth except at one point, where the weight of spoil bank forced into the cut soft underlying material from a previous river channel which it crossed. Additional work is required to bring the cut to full width and regular alignment, especially at the point just referred to and at the upper end of the cut-off, where the levee on one side was not cut because of flood conditions at the time. The cut-off is now used by all the river traffic. Administrative expenses have increased the total expenditures during fiscal year to $20,411.02.

(C) San Joaquin River, Fremont Channel and McLeod Lake, Arms of Stockton Harbor.

The approved depths of McLeod Lake and Fremont Channel, which are included in Stockton Harbor project, are believed to exist unimpaired, although no survey of the area has been made; no maintenance work has been required.

APPROPRIATIONS.

Date of rivers and harbors act	Maintenance	9-foot channel and cut-offs	Fremont Channel and McLeod Lake, arms of Stockton Harbor		Total
			Improvement	Maintenance	
Aug. 14, 1876	$20,000 00				$20,000 00
June 14, 1880	20,000 00				20,000 00
March 3, 1881	40,000 00				40,000 00
Aug. 2, 1882	40,000 00				40,000 00
July 5, 1884	20,000 00				20,000 00
Aug. 5, 1886	18,750 00				18,750 00
Aug. 11, 1888	25,000 00				25,000 00
Sept. 19, 1890	75,000 00				75,000 00
July 13, 1892	65,000 00				65,000 00
Aug. 18, 1894	50,000 00				50,000 00
June 3, 1895	67,750 00				67,750 00
March 3, 1899	20,000 00				20,000 00
June 13, 1902	18,000 00				18,000 00
April 28, 1904	[1]35,170 00				35,170 00
March 3, 1905	20,000 00				20,000 00
March 2, 1907	30,000 00				30,000 00
March 3, 1909	[2]20,000 00				20,000 00
June 25, 1910	35,000 00	$40,000 00			75,000 00
Feb. 27, 1911	25,000 00				25,000 00
July 25, 1912	40,000 00		$11,000 00		51,000 00
March 4, 1913		159,632 00			159,632 00
March 4, 1913	[3]25,000 00			[3]$500 00	[3]25,500 00
		$199,632 00			$910,802 00
Withdrawn under act of Mar. 4, 1915		30,000 00			30,000 00
Net totals	$699,670 00	$169,632 00	$11,000 00	$500 00	$880,802 00
Treasury settlements, Oct. 11, 1911	11 25				11 25
Grand totals	$699,681 25	$169,632 00	$11,000 00	$500 00	$880,813 25

[1]Allotted May 31, 1904.
[2]Allotted April 10, 1909.
[3]Apportioned by War Department from $26,500 appropriation which provides for three separate projects in lump sum.

Contracts in Force.

(a) *Dredging in San Joaquin River and Stockton Channel, Cal.*
Name of contractor: Standard American Dredging Company.
Date of contract: July 17, 1914.
Date of approval: August 8, 1914.
Date fixed for commencement: September 10, 1914.
Actual date of commencement: October 3, 1914.
Date fixed for completion: December 9, 1914.
Percentage of completion at end of fiscal year: 100.
Amount of contract: $11,146.
Prices, per unit: 9.9 cents per cubic yard, 10 cents per cubic yard.

(b) *Lease for dredge to be used in making cut-off "C" in San Joaquin River, Cal.*
Name of contractor: American Dredging Company.
Date of contract: September 26, 1914.
Date of approval: Lease, approval not required.
Date fixed for commencement: October 6, 1914.
Actual date of commencement: October 6, 1914.
Date fixed for completion: January 21, 1915.
Percentage of completion at end of fiscal year: 100.
Amount of contract: $16,055.56.
Price, per unit: $175 per day.

(c) *Lease for dredge to be used in making cut-off "C" in San Joaquin River, Cal.*
Name of contractor: American Dredging Company.
Date of contract: January 11, 1915.
Date of approval: Lease, approval not required.
Date fixed for commencement: January 22, 1915.
Actual date of commencement: January 22, 1915.
Date fixed for completion: February 28, 1915.
Percentage of completion at end of fiscal year: 100.[1]
Amount of contract: $5,600 as made; $1,952.83 allowed for work.
Price, per unit: $175 per day.

COMMERCIAL STATISTICS.

Vessel Classification.

Class	Number	Net registered tonnage	Passengers
Registered—			
Steamers	22	7,373	72,313
Gas	64	1,030	110,343
Sailing	28	1,509	----------
Unrigged	39	6,033	----------
Unregistered—			
Gas	13	----------	7,011
Sailing	5	----------	----------
Unrigged	21	----------	----------
Totals	192	15,945	189,667

[1]Not in strict accordance with contract terms.

FREIGHT TRAFFIC.

Article	Amount		Valuation	Tonnage for which rates and distances are known	Average haul or distance freight was carried (miles)	Rate per ton-mile
	Customary units	Short tons				
Coal	1,702 tons	1,702	$13,616 00	1,526	82.5	$0.020
Fuel oil	435,660 barrels	70,492	331,312 40	16,337	74.2	.014
Gasoline	27,531 drums	11,816	543,536 00			
Distillate	16,747 drums	7,700	219,450 00	30	40	.037
Coal oil	9,638 cases	395	9,875 00			
Lubricating oil		60	3,900 00			
Machinery	2,503 tons	2,503	375,450 00			
Autos	106	159	111,300 00			
Wagons	310	310	23,250 00	164	62.5	.048
Buggies	108	32	4,480 00			
Sand	21,237 cubic yds.	31,855	21,238 60	31,605	72.7	.008
Brick	4,280 M	10,699	32,097 00	10,691	49.8	.020
Cement	115 barrels	23	230 00	23	22.6	.072
Crushed rock	11,083 cubic yds.	2,525	2,525 00	2,525	34	.009
Lumber	17,317 M feet	25,976	259,760 00	12,021	33.2	.018
Piles	1,420	1,065	7,100 00			
Shingles	280 M	21	420 00	16	45	.010
Shooks	610 M feet	610	16,775 00	10	80	.012
Cordwood	3,199 cords	6,398	15,995 00	6,398	61.3	.023
Wheat	23,381 tons	23,381	818,335 00	586	58.6	.040
Barley	107,544 tons	107,544	2,473,512 00	82,987	80.3	.015
Oats	2,221 tons	2,221	66,630 00	1,715	61	.025
Corn	1,487 tons	1,487	52,045 00	823	44	.025
Flour	7,160 barrels	716	50,120 00	357	39.3	.011
Millstuff[1]	54,972 tons	54,972	2,748,600 00	3,297	75	.027
Rice	32 tons	32	2,560 00	10	15	.200
Beans	27,218 tons	27,218	1,905,260 00	8,541	74.7	.014
Potatoes	144,155 tons	144,155	2,883,100 00	95,022	55.8	.020
Onions	28,785 tons	28,785	287,850 00	23,896	62.5	.016
Asparagus	4,188 tons	4,188	209,400 00	3,542	15.1	.171
Other vegetables	26,321 tons	26,321	1,316,050 00	812	38.4	.043
Hay	12,542 tons	12,542	100,336 00	10,095	31.8	.024
Wool	5 tons	5	1,800 00			
Hides	160 bundles	72	36,000 00			
Horses	1,768 head	1,060	265,000 00	876	51.1	.072
Cattle	1,985 head	695	97,300 00	525	26.7	.107
Sheep	68,576 head	4,286	514,320 00	4,261	28.5	.063
Hogs	440 head	33	5,940 00	29	35.5	.108
Live stock		777	116,550 00			
Salt	20 tons	20	300 00	20	115	.017
Fruit, fresh	226 tons	226	15,820 00			
Fruit, dried	2 tons	2	300 00			
General merchandise	152,031 tons	152,031	19,003,875 00	7,212	73.7	.027
Canned goods	57,400 cases	1,722	206,640 00	3	20.3	.137
Hemp	345 bales	50	5,000 00			
Beet pulp	450 tons	450	1,350 00			
Soda water	3,392 cases	212	11,660 00			
Beer	17,824 cases	1,114	66,840 00			
Meats	115 tons	115	27,600 00	1	25	.080
Fish	582 tons	582	69,840 00	317	79.3	.019
Dairy produce	474 tons	474	94,800 00			
Miscellaneous	327 tons	327	32,700 00	31	24.6	.091
Totals		722,156	$35,479,741 00			

[1]Includes much flour.

Note.—Attention is invited to the fact that, in general, rates and distances carried are known for short hauls of small lots only and the rates per ton-mile are therefore necessarily large.

2. Stockton and Mormon Channels (Diverting Canal), Cal.

During July $250 was expended, by oral agreement for a particular piece of work, in clearing the canal of undergrowth. Administrative charges have increased the total spent during the fiscal year to $334.26.

APPROPRIATIONS.

Date of river and harbor acts	Improvement	Maintenance	Total
June 13, 1902	$50,000 00		$50,000 00
March 3, 1903	50,000 00		50,000 00
April 28, 1904	75,000 00		75,000 00
March 3, 1905	49,316 00		49,316 00
March 4, 1909	56,079 00		56,079 00
March 4, 1913		[1]$1,000 00	1,000 00
Totals	$280,395 00	$1,000 00	$281,395 00
Received by treasury settlements October 11, 1911			8 33
Grand total			$281,403 33

Contracts in Force.

There were no contracts in force during the year.

Commercial Statistics.

See "Commercial Statistics" for San Joaquin, Cal., page 3352.

3. Mokelumne River, Cal.

There was no work done on this stream during the year. Of the total amount expended, $243.20, the sum of $43.20 was to cover outstanding liabilities from preceding year, and $200 was for administration.

APPROPRIATIONS.

Improving Mokelumne River, California.

River and Harbor acts of—	
July 5, 1884	$8,500
Aug. 5, 1886	2,500
Aug. 11, 1888	2,000
July 13, 1892	2,500
Aug. 18, 1894	2,500
Mar. 3, 1905	2,500
Mar. 2, 1907	2,500
June 25, 1910	2,000
Feb. 27, 1911	5,000
Mar. 4, 1913	1,000
Total	[1] $31,000

Contracts in Force.

There were no contracts in force during the year.

[1]Allotted from $26,500 appropriation of March 4, 1913, which provided for three projects in lump sum.

COMMERCIAL STATISTICS.

Vessel Classifications.

Class	Number	Net registered tonnage	Passengers
Registered:			
Steamers	7	2,185	1,326
Gas	28	345	
Sailing	5	217	
Unrigged	16	1,720	
Unregistered:			
Steamers			
Gas	5		668
Sailing	3		
Unrigged	8		
Total	72	4,467	1,994

NOTE.—Through the Southern Pacific Railway bridge over Snodgrass Slough, a tributary of the Mokelumne River, 60 gas boats, 2 sailing vessels, 46 barges and 6 dredges passed during the year.

FREIGHT TRAFFIC.

Article	Amount: Customary units	Amount: Short tons	Valuation	Tonnage for which rates and distances are known	Average haul or distance freight was carried (miles)	Rate per ton-mile
Coal	40	40	$720 00	40	90.0	$0.016
Fuel oil	8,035 barrels	1,306	6,420 00	767	57.6	.018
Gasoline	77 drums	33	1,518 00			
Distillate	790 drums	363	10,345 50	12	40.0	.038
Coal oil	537 cases	22	550 00			
Lubricating oil		15	975 00			
Machinery		119	17,850 00	7	15.0	.133
Wagons	40	40	3,000 00	37	50.0	.120
Buggies	3	1	140 00			
Brick	2 M	5	15 00	5	50.0	.040
Lumber	945 M	1,412	14,120 00	251	49.8	.035
Shingles	53 M	4	80 00	4	40.0	.043
Shooks	5 M feet	5	137 50			
Cordwood	110 cords	220	550 00	220	24.5	.036
Wheat	10 tons	10	350 00			
Barley	6,778 tons	6,778	155,894 00	3,702	59.1	.019
Millstuff[1]	138 tons	138	6,900 00	138	50.0	.040
Beans	3,768 tons	3,768	263,760 00	737	48.6	.021
Potatoes	37,451 tons	37,451	749,020 00	10,340	34.8	.036
Onions	87 tons	87	870 00	87	50.0	.024
Asparagus	421 tons	421	21,050 00			
Other vegetables	4,486 tons	4,486	224,300 00	769	49.7	.047
Hay	640 tons	640	5,120 00	365	35.9	.060
Horses	345 head	207	51,750 00	87	43.5	.084
Cattle	6 head	2	280 00			
Sheep	15,000 head	910	112,800 00			
Fruit, fresh	124	124	8,680 00			
Grapes	66 tons	6	1,650 00	66	45.0	.056
General merchandise	8,493 tons	8,493	1,061,625 00	445	47.8	.012
Canned goods	50,000 cases	1,507	180,840 00			
Fish	318 tons	518	38,160 00	158	65.0	.023
Dairy produce	462 tons	462	92,400 00			
Beer	3,840 cases	240	14,400 00			
Totals		69,723	$3,045,870 00			

[1]Includes flour.

NOTE.—Attention is invited to the fact that, in general, rates and distances carried are known for the short hauls of small lots only and the rates per ton-mile are therefore necessarily large.

RIVER WORK.

All matters of drainage, improving and rectifying river channels and other work on any river or slough connecting with San Francisco Bay, San Pablo Bay, and Suisun Bay, and the tidewaters flowing in said bays wherein state moneys are expended, are placed under the management of the Department of Engineering. The department has charge of all expenditures, unless otherwise specially provided by law, for all public works relating to general river and harbor improvements, reclamation and drainage of lands, purchase, construction and operation of dredges and other appliances and including the acquisition by purchase, condemnation or otherwise of rights of way for any of said purposes.

Whenever work in the interests of navigation and the control and maintenance of stable conditions of the rivers involves also direct benefits or protection to the lands seeking to have the work done by the state the lands so benefited are required to bear a portion of the cost of the work, usually one-half to two-thirds, the state paying the remaining portion.

Owing to the fact that the climate of the Great Valley is passing through a "dry" cycle, no great floods have occurred in either stream system for several years. Not since 1911 has the San Joaquin experienced a flood, and 1909 was the last high water in the Sacramento which reached dangerous conditions.

As a consequence of several years immunity from floods, there have been no crevasses formed requiring closures or extensive protection works.

Long-continued low plane of the water surface, however, is conducive to active caving of the alluvial banks, and in places this has occurred to the great loss of good land and destruction of levees, creating conditions where serious breaches would likely occur at the next flood. The department has kept close watch of such conditions, and wherever danger threatened has applied remedial measures.

The principal work of the river improvement division since the last report has been to repair and maintain revetment previously laid, and to place new revetment where conditions demanded.

Several types of bank protection have been used by the state and by private reclamation projects. Formerly where current or wave action attacked a levee the slope was protected by covering it with brush held down with poles laid transversely and tied with wire to stakes driven into the soil.

Jetties of brush and posts or piles have been extensively used. A patented cellular jetty was introduced five or six years ago which its advocates thought would always deflect the current from the bank

with sure benefit. In practice it was found to succeed in some places, but absolutely failed to accomplish its purpose in others.

Many miles of brush bulkhead along the foot of the banks have been constructed, some successfully performing their functions and others failing. Plank bulkheads on piles, sheet piles and other devices have been used, but all structures of wood are perishable and of short duration. Attempts have been made to use concrete in various ways. Several miles of levee have been covered on the slope with concrete pavement. Usually this is two to three inches thick, laid on as a continuous sheet, frequently having light steel reinforcement. Sometimes expansion joints are introduced and other times the slab is continuous for long distances.

The state experimented with a concrete covering laid in separate blocks 13 x 60 inches and 3 inches thick. The blocks were manufactured in a plant and brought to the bank, where they were laid on the slope and strung together with cables anchored into the top of the levee. The theory of the inventor was that being fastened to cables the "mattress" would have great flexibility and should undercutting occur the "mat" would accommodate itself to the unevenness of the slope and continue to protect it from current action.

In practice it was found that if undercutting occurred at all, the earth would slide underneath the concrete, leaving holes, and while the flexibility did allow the mat to settle to some extent, it was not sufficient to follow extensive subsidences, and consequently the blocks would break or pull apart, leaving holes through which the water would attack the earth slope. Generally, if no undercutting took place the revetment stood well and thoroughly protected the bank, and in that used by the state a portion was provided with a sheet-piling toe wall which, protecting the bank slope from undercutting, has rendered the flexible mattress very effective. But this is accomplished by a condition where flexibility is not required, hence a solid sheet of concrete covering the slope would be just as effective and would cost much less than the other.

The question of bank protection is one that engages serious thought and the Department of Engineering has given much study to the subject and some experiment with a view of determining a method that will be effective and yet the cost of which will not be prohibitive.

The causes which lead to the disintegration of the river banks are current action and wave action. The current usually attacks the foot of the bank, eroding the earth, and causing the overhanging material above the erosion to break off and fall into the stream. This condition is aggravated by the overload from levees being placed in the bank as close as possible to the edge. Erosion once started soon reaches the

PLATE XIII.

Bank Protection—Unloading brush for a mattress.

Bank Protection—Beginning a brush mattress.

line of the levee when both bank and levee quickly fall in, creating a breach which in high water becomes a crevasse. Wave action, induced by wind or the swell of passing water craft, attacks the bank at the water's edge. The waves being driven against the bank or up the slope of a levee, displace portions of the earth surface. Having once started disintegration, every wave increases the displacement. The material falls into the water, and the final result is the same as that of current erosion, the destruction of the bank at the point of attack.

Along the river channels the width of water surface is seldom sufficient for waves raised by the wind to acquire sufficient impetus to have much effect on the banks, but in the confined space of a channel the waves caused by a steamer make great havoc.

Current erosion is generally confined to the convex side of bends, but the waves from water craft attack the entire length of both banks. Furthermore, their effect is felt at every stage of the water surface, and in such streams as the Sacramento River, where the range from low- to high-water stages is nearly 30 feet, there is presented a width of 60 to 100 feet, depending upon the slope, every part of which is subject to attack and injury from the waves, and it is only where the material is particularly firm or is protected by vegetable growth that it does not yield to the constant pounding of the waves.

This condition is becoming more pronounced every year. The rapid increase in the number of river craft increases the frequency of the waves and the increase in size and speed of the boats enlarges the swell and thus augments the destructive effects.

It is no stretch of the imagination to believe that in a few years the increase of commerce on the inland waterways carried in more numerous, larger and swifter craft will create conditions requiring some kind of protection to the entire length of both banks of the Sacramento below the city and probably much of the river above.

Owing to the broader expanse of water in the lower San Joaquin, the above-described conditions do not obtain in the same degree. Wave action from winds is more pronounced, but the nature of the material of the banks enables them to withstand the pounding, and the narrow range between low-water and flood planes modify greatly the cost of maintenance.

The cheapest and at the same time most effective bank protection yet tried by the department is a type of flexible brush mattress woven of willow brush fascines and wire cables, anchored into the bank and weighted down with attached concrete or stone weights.

The woven brush mattress has long been used by the government for protecting the banks of the Mississippi, Missouri and other large streams, but the system used by the Department of Engineering differs from

the government method in having the weights attached to the mattress instead of deposited loosely on its surface. Formerly the state placed considerable quantities of the rock-laden type, but in many cases erosion took place at the edge of the mattress, causing it to sink lower. The slope then being increased the rocks rolled off, the brush floated in the water, was torn loose from its mooring and carried away.

By attaching the weights to the cables woven in the mattress and fastened in the bank, the whole remains in place even though erosion should take place to such an extent as to hang the mattress like a curtain over the bank.

An advantage of this kind of work is that it can be extended far into the stream, covering the bed beyond any probable chance of erosion starting under the edge.

A disadvantage of this type is that, being made of brush, the durability of the material is limited. Where it is constantly submerged it will last a long time, but above permanent water surface the wood decays and in a few years must be renewed. In many situations, however, when the brush is cut late in the fall, and after being laid is covered with a few inches of earth or sand the brush will sprout and grow into a dense thicket of fine brush affording a living and permanent protection. It frequently happens, though, that the brush sprouts will die unless irrigated during the first summer.

Several of the mattresses laid by the department have been treated as indicated above, and now present an impregnable defense to the onslaughts of the water. When the brush fails to grow, the same effect is obtained by driving down green willow stakes at close intervals over the mattress.

A description of the river work executed during the two years just passed, follows:

SACRAMENTO RIVER.

Crouch Landing. This point, known also as Bower's Ranch, continues to give concern to the landowners adjacent. Erosion of the bank around a sharp bend of the river has moved that bank several hundred feet inland, washing away many acres of valuable land.

Several attempts have been made to arrest the erosion, but owing to a combination of circumstances—a high bank of friable earth underlaid by a stratum of loose gravel situated in the "whirl" of a strong current—requires treatment that will cost more than the immediate beneficiaries care to incur. Should the erosion extend to a point where danger of a break forming a new channel to the injury of navigation and the destruction of a large area of valuable lands, no doubt cooperation can be effected for constructing adequate protective works.

PLATE XIV.

Bank Protection—Weaving the mat.

Bank Protection—Preparing to launch a mat.

The only work attempted since the last report was trimming the bank for a slope of 1 to 1 for a length of 2,100 feet, grubbing brush and clearing debris from ten acres of river bed, and clearing out a shallow cut-off channel across the chord of the bend.

The cost of this work was $1,908.73, one-half of which was paid by the adjoining landowners.

Meridian. At a bend in the river, beginning about a half mile above the Northern Electric Railroad bridge at Meridian, erosion had attacked the left bank and advanced well into the levee. A breach here would result in great injury to the lands between the river and Butte Slough, damage to the railroad and the power lines crossing the basin, and destruction to the town of Meridian with probable loss of life, in addition to the inevitable injury to navigation which always follows a serious break.

Cooperative arrangements were made with the property interests threatened and two pieces of flexible brush mattress were laid on the stretch threatened, covering 124,000 square feet of bank.

The total cost of the work was $13,739.45, one-third of which was paid from state funds and two-thirds by the property owners.

Collins Eddy. This is a very sharp bend of the river, the stream turning its course 300 degrees in a distance of one-quarter of a mile. The current had washed away the bank and cut into the levee, causing the property owners to move buildings farther away. A breach here would entail great damage to adjacent property and injury to navigation on the river.

The federal engineers approved the proposed work and contributed piles and drove them in place to the extent of about $2,000. Owing to delays in effecting cooperative agreements with the bank owners, work was not commenced until December, 1914. High water caused a suspension of work and when the flood had subsided considerable of the work placed had been washed away. Operations were resumed the next year. In addition to repairing those portions of the previous year's work left standing, a part of that washed out was replaced with the same type of pile and brush bulkhead, but it was found that bulkheads would not stand the impact of barges thrown against them by the whirling current. A brush mattress was then laid on the bank subject to the hard usage, and owing to the violence of the pounding it would receive from passing craft it was made much heavier than usual, being woven with a thickness of three feet at the lower selvage.

The mattress laid measured 420 feet long, average 70 feet wide, aggregated 29,400 square feet and contained 373 cords of brush.

The previous year's work had taken all of the brush in the immediate vicinity so that used for this work was obtained at Knights Landing and transported more than twenty miles by barge to the work.

The total cost of both years work was $8,241.17, which was borne equally by the state and the property owners. These figures do not include about $2,000 contributed in piling by the government in December, 1914.

Edwards Break. This name is applied to the vicinity of a crevasse which occurred in the left bank of the river opposite Sutterville a short distance below the corporate limits of the city of Sacramento. The break occurred during the flood of 1904 and spread devastation throughout the Sacramento basin to the Mokelumne River, causing that stream to overflow its banks and spread its water almost to the city of Stockton. Only by dint of constant effort was the Y street levee maintained as a bulwark against the flood's invasion of the streets of the capital city. It is said to have cost the state more than $100,000 to close the break.

For many years the levees for a distance of more than a mile have been gradually succumbing to attacks of current and wave, and each report of this department has detailed efforts to maintain them in a safe condition. Several stretches of brush mattress have been laid from time to time to hold the most dangerous places.

Reclamation District No. 535, in 1914 proposed a plan of permanent improvement to consist of covering the slope of the bank next the river with a concrete cover laid in sections fastened together with cables so as to give (as the patentee thought) a degree of flexibility to the covering which would enable it to adapt itself to inequalities of the slope in case of settlement of the soil underneath.

The work executed was not continuous, as any bank that was holding firmly was not covered. The aggregate of the concrete laid was 8,141 lineal feet covering 404,949 square feet.

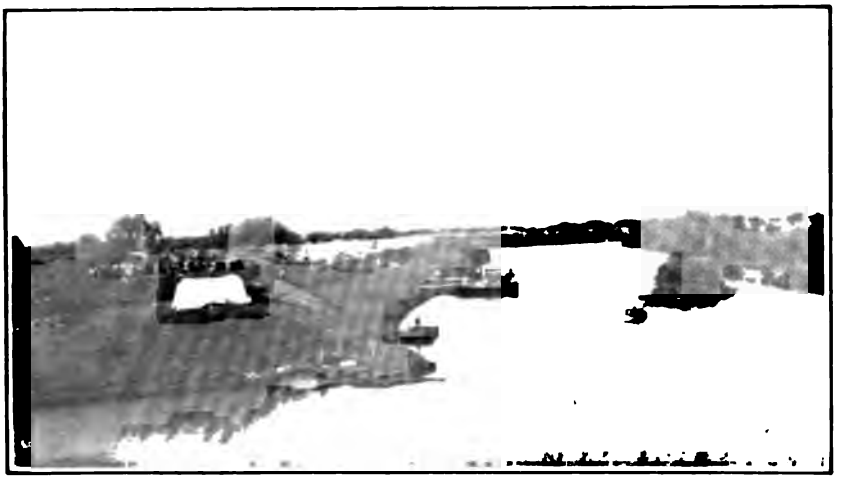
Owing to the settlement of the earth as work progressed, it was necessary to take up and relay a considerable portion. Also to prevent further settlement a sheet pile toe wall was driven at the toe of portions of the work. This was found very necessary wherever the material of the bank was sandy, or where because of restricted right of way the slope was made steeper than $1\frac{1}{2}$ to 1.

The total cost, including toe walls and relaying of damaged work, was $86,451.34, amounting to $0.213 per square foot.

Freeport. Conditions at Freeport have given the authorities much concern. A length of about 6,000 feet of the left bank in a long bend is affected. The levee is high and composed largely of sandy materials. The land adjacent is low and should a break occur the flood would flow across the intervening country to the Mokelumne River and, should that stream be full at the time, its channel would be gorged and break over to the south, inundating the territory toward Stockton, as occurred at the time of the Edwards break, detailed above.

PLATE XV.

"Let 'er go!" Launching a completed mat.



Bank Protection—Finishing a job.

The property immediately back of the levee is not in a reclamation district and it has been impossible to enlist cooperative action.

The department in cooperation with the county of Sacramento in 1914 placed some revetment in the worst places, but owing to lack of funds it was mostly of a temporary character.

Each year since, this department has continued to maintain the levee against the encroachment of the current, but always with works of a temporary character, the only cooperative funds available being $1,000 from the county.

In January, 1916, conditions were so bad that it was necessary to lay 2,060 lineal feet of standard brush mattress.

The expenditures at this place during the biennium just closing have been as follows:

March and April, 1915	$2,031 54	
December, 1915, January, 1916	2,372 21	
		$4,403 75
Of the total cost, the county of Sacramento paid	$1,000 00	
Sacramento and San Joaquin drainage district	186 11	
		1,186 11
The state		$3,217 64

Sherman Island. Most of the work executed for the security of the banks along the shores of this island has required little attention. The work of enlarging the waterway of Sacramento River by cooperation between the government and the state has gone steadily on and its effects are very marked in the reduced amount of damage done to the levees.

Three-mile Slough is a branch of the Sacramento River between Sherman and Brannan islands and connecting the Sacramento and San Joaquin rivers. About half a mile from the head the slough turns abruptly to the left, and the swirling waters have washed out a deep pool which has a tendency to constantly work inland.

Several years ago a bulkhead of piles and brush was constructed here to stop the erosion. The depth of water is more than fifty feet and the bottom is hardpan so that piles can not be driven with sufficient penetration to make them secure. Owing to the swift and whirling current, passing steamers and barges are sometimes thrown against the bulkhead with great force, breaking the piles or loosening them. For this reason annual repairs are necessary. During the last two years repairs have been made in cooperation with the trustees of Reclamation District No. 341, costing $2,614.37, of which the district has paid one-half.

SAN JOAQUIN RIVER.

Until investigations now being made by the state and federal agencies shall be completed and a plan formulated for flood control in the interests of navigation and reclamation, it has been considered inexpedient for the Department of Engineering to do more than to endeavor to maintain conditions as they are and has confined its activities to assisting in the maintenance of levees and installation of bank protection where conditions became dangerous, or where navigation could be permanently benefited.

Smith's Canal. Protection to the bank of the river at the junction of Smith's Canal as projected at the close of the last report was constructed at a cost in excess of $1,200, of which the state contributed $587 and adjoining property owners the remainder.

Rough and Ready Island. The legislature in 1911 appropriated $15,000 for acquiring rights of way to enable the government to make two cut-offs of bends in the San Joaquin. The rights were obtained and the cuts are at this writing very nearly completed.

Stockton Channel. The national government contemplates enlarging and improving the shipway of Stockton Channel, for which rights of way are required.

Reclamation District No. 511. The brush mattress being placed at the time of the last report was completed at an expense of $4,622.88, the state and district each paying half.

Reclamation District No. 17. Several places occur in the banks of the river above the diversion of Old River where the bank and levees are subject to severe strain in times of flood, and which if allowed to break would flood the country to the north almost to Stockton. It requires constant watching to prevent conditions reaching a dangerous stage. By cooperation with the property owners, the banks have been maintained so that no serious breaks have occurred for several years.

An old brush mattress at Caloris ranch was repaired and improved with 110 lineal feet of new mattress, 1,400 lineal feet was laid near the county highway bridge on the Lathrop-Tracy road, and 300 lineal feet at Walthall Slough, aggregating 1,810 lineal feet of revetment amounting to 136,700 square feet at a cost of $12,417.34, one-half being paid by the district.

Paradise Bend. Three units of revetment were placed here during the last biennial period, a forecast of which was made in the last report. The location and extent of the units appear as follows:

Fink's Pump ------Dimensions	545 x 75 ft., area	40,875 sq. ft.
At Paradise Cut----Dimensions	75 x 45 ft., area	3,375 sq. ft.
Below Paradise Cut-Dimensions	714 x 80 ft., area	57,120 sq. ft.
Totals ----------1334 lin. ft.		101,370 sq. ft.

The total cost of the work aggregated the sum of $7,760.37, borne equally by the state and the property owners.

Banta Reclamation District. The conditions described above under the caption "District 17," obtained to an aggravated degree above the head of Paradise Cut. The department had previously constructed revetment at Lorenzen's Whirlpool and during the past two years has found it necessary to extend the work at that place and place protection at others, as follows:

Upper end of district, mattress	985 x 85 =	83,725 sq. ft.
	50 x 40 =	2,000 sq. ft.
Above mat at Lorenzen	100 x 80 =	8,000 sq. ft.
Below mat at Lorenzen	100 x 80 =	8,000 sq. ft.
Near Paradise Cut	460 x 80 =	34,500 sq. ft.
Totals	1695 lin. ft.	136,225 sq. ft.

The total aggregate cost of this work was $10,167.97; the state and property owners each paying one-half.

Unfinished work. In addition to the work accomplished according to the foregoing description, the department is engaged in executing new work at New Banta Reclamation District and Paradise Dam, estimated to cost $2,500 and $1,800, respectively. One-half of the estimated cost in each case is deposited by the property owners to cover their share of the expense.

Negotiations are pending for additional work to be done at Districts Nos. 17 and 544, but are not yet concluded.

Channel Explorations. A partial revival of navigation seems imminent on the San Joaquin River above Stockton. This being considered worthy of encouragement the department made a reconnaissance of the channel from Stockton to Hill's Ferry, a distance of 87 miles. It was found that to clear the channel of snags so as to render navigation safe at low and mid-stages of water, and do thoroughly as the department would only undertake to do, would require an expenditure of funds which the department was not prepared to meet alone. Effort to enlist the cooperation of navigation interests failed and therefore nothing has been attempted in the way of clearing the channel, nor is any extended effort contemplated, at least until the research now being prosecuted shall develop a flood control plan, in the carrying out of which the clearing of channels will necessarily be a part.

METHODS OF WORK.

The work of the river division is so erratic in its character that a large force of laborers is not employed continuously. Sometimes many "jobs" will be under way at once and several hundred men may be

employed. Again there will be months when no constructive work will be in progress. Such conditions make employment transient in character and consequently no great number of men acquire experience in the work.

There are several men, however, who always seek employment with the department whenever work is to be had. They are steady and reliable; many of them saving their wages and depositing the money in savings banks. Such men can always be depended upon to be loyal to the employer in emergencies. It has been the policy of the department to give such men every consideration, and effort is made to find employment for them whenever it becomes necessary to suspend work on the river.

This policy has resulted in creating a small but dependable force of laborers skilled in the several manual occupations required in work on the rivers. These men are all enrolled in the civil service, and are an honor to that institution, but when the department requires a large force of men it is, perforce, compelled to draw upon the army of "professional unemployed."

Some of these also are enrolled as civil service employees, but the experience of the department is that even they are but little better than the unregistered "floater." In view of that fact and the further fact that the average duration of employment of transients, according to their own statements, is only about three and a half weeks it seems doubtful if any good is accomplished by maintaining a registered list of laborers for transient or temporary positions.

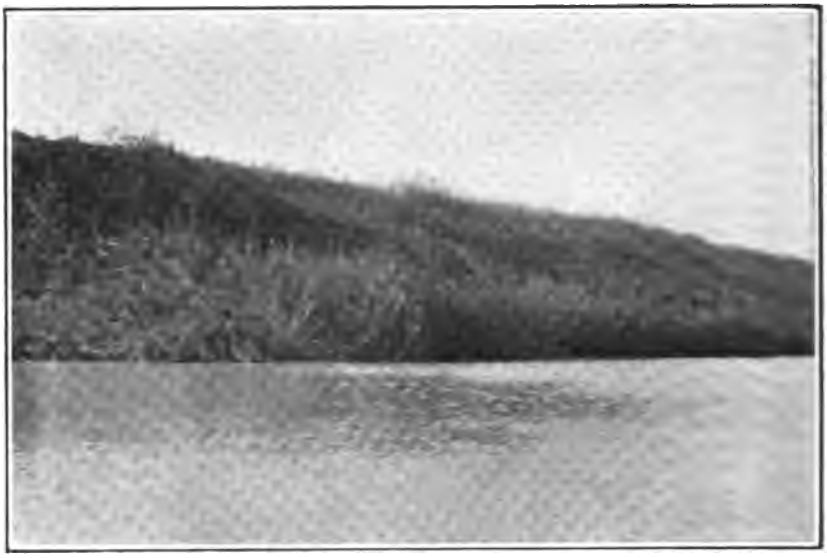
The department has many times made requests upon the Civil Service Commission for a force of 20 or 30 laborers and have only three or four to report for work. Recourse would then be had under authority of the commission to the employment of others, but in each case delay was encountered, and loss, in not having a full crew.

CAMP ARRANGEMENTS.

A separate camp is established at the site of each piece of work, and the men boarded at the camp. Care is exercised to keep the commissary up to a high standard, all foodstuffs being of fine quality and in good variety. Kitchen arrangements are complete and convenient, and cooking is required to be well and cleanly done. Kitchen and dining quarters are well screened and all garbage is taken care of in a sanitary manner. Large ice chests are provided for all perishable foods. Where the domestic water supply is not above suspicion all drinking water is either boiled or filtered or both.

Tents are provided for sleeping quarters restricting their occupancy to two persons to each ordinary-sized tent. The men are required to

PLATE XVI.



Bank Protection—A brush mattress with the brush grown into a dense mass, affording complete protection.

A heavy tow—a rowboat driven by a detachable motor, towing equipment.

furnish their own blankets, but each man is furnished with an iron-frame spring cot. Clean straw is provided and changed every week or whenever a cot is vacated. Cots are frequently washed with germicide solution.

Bathing facilities are provided, the tubs and showers furnished with hot and cold water. The water for bathing is heated by the same boiler furnishing water for washing clothes. Plenty of soap is furnished to each man. A large assembly tent is provided with a stove where men who get wet may dry their clothes before going to their individual quarters. Most of the small tents are furnished with heating stoves. In short every effort is made to maintain the camp in a comfortable and healthful condition.

Equipment. The river division possesses one large working barge 45 x 100 feet, one small barge 10 x 20, a small pile driver, one small pontoon fire engine, a kitchen houseboat, one towing launch, one fast dispatch launch, five rowboats and three portable skiff engines capable of driving the rowboats five to seven miles an hour. When work is required in several places at one time it becomes necessary to rent barges and hire towboats.

MISCELLANEOUS.

State Supervision of Dams. In the last report attention was called to the growing number of high dams being constructed for industrial purposes without supervision by public authority. Instances were cited where failure of dams with possible loss of life and property had been averted more by good fortune than otherwise.

In response to the suggestions made for provision to place all dams under state inspection and supervision, the legislature enacted an amendment to the act creating the Department of Engineering, containing the following provision:

> "It shall be the duty of the state department of engineering to pass upon all plans, specifications and estimates for the construction of dams now already constructed, in process of construction, or proposed to be constructed for the impounding of water other than the dams now coming under the authority of the California railroad commission." (Chapter 394, statutes 1915.)

The intent of the above quoted law is plain, but it is submitted that it confers little authority upon the Department of Engineering. "To pass upon plans" is not sufficient without authority to alter the plans if they are defective and to enforce compliance in construction with approved plans and specifications, or if the structure is already constructed and found to be unsafe the state's agent should be clothed with power to compel the adoption of measures to make it safe.

There are dams in course of construction or contemplated which will be more than 300 feet in height and hold in the canyons above them billions of cubic feet of water. The results from a failure of such a structure are appalling to contemplate.

It will be contended that the projectors of all enterprises requiring such structures employ the best engineering talent to be had and use every precaution to ensure the safety of the work. That may be granted, but the archives of the Department of Engineering contain the record of at least one dam constructed by a wealthy corporation according to plans and specifications which would be pronounced all-sufficient by any engineer. They would have been "passed upon" favorably by the Department of Engineering if submitted to it. Yet exploration extending to the interior of the dam showed that the specifications had been grossly ignored, and hidden disintegration had already progressed far. The company was not to blame, excepting for lax inspection, but some one had deliberately "skimped" the work

and endangered the lives of hundreds of people living below the dam.

The law governing the Department of Engineering provides that:

> "All inspectors employed by the state engineer on any public work shall render to the state engineer a full, true and correct report of the kind, manner and progress of all work upon which he is such inspector. Any inspector who shall render a false report knowing the same to be false shall be guilty of a *felony.*"

Also,

> "Any contractor or his agent or employee who shall knowingly permit the violation of the contract of such contractor to the injury of the state, or any agent or employee of any contractor who shall have knowledge of any work being done in violation of contract *and does not immediately notify* the department of engineering or the inspector upon said work in regard to the same *is guilty of a felony* and upon conviction thereof, shall be confined in the state prison for not less than one year nor more than five years and be liable to the state for double the amount the state may have lost or be liable to lose by reason thereof." (Chapter 38, statutes 1909.)

It is urged that the same penalty should apply to any owner, contractor or employee engaged in erecting any structure the weakness of which would be a menace to the lives and property of other people.

The Department of Engineering, feeling that the authority to "pass upon plans" is insufficient, and not having funds with which to cause inspections to be made, has confined its activities to only such cases as were brought to its attention by complaints.

Acting upon complaints or upon strong rumors that certain works were suspected of being inadequate, the State Engineer personally examined the Bear Valley dam in San Bernardino County, the Escondido dam in San Diego County, both constructed long ago, and the Woodward dam of the South San Joaquin Irrigation District, situated in Stanislaus County, being constructed, and in each case found that expressed fears as to their safety were without foundation.

The failure of the Lower Otay dam near San Diego, with a loss of several lives and the destruction of an immense amount of property, has been so well described in the news and technical press that it is unnecessary to enter into the details here. That dam was constructed without engineering advice in design or supervision in construction, and had been severely criticized by engineers as a departure from safe practice. Its failure at the first time that the reservoir was filled, with the dire results following, has aroused great fear in the minds of people residing below other dams, constructed or contemplated, and they are entitled to protection from a repetition of the Otay disaster so far as it is in the power of the state to give it.

It is urged that the inadequate law relating to state supervision of dams be strengthened by giving its agents ample powers, and that severe penalties be imposed for fraud in the construction of any important work affecting life and property, whether that work be public or private.

Bridges on Navigable Streams. Under the provisions of chapter 68, statutes of 1881, it is required that the plans for all bridges to be erected over navigable streams shall be submitted to the State Engineer, who shall designate the width of draw.

This office is convinced that the reviewing authority should have power also to prescribe other matters affecting the regimen of the stream, such as the location and position of piers and abutments, and protection to banks. Neglect of these matters, it is believed, was responsible a few years ago for serious breaks in river levee and the partial destruction of the offending bridge, the loss of which interrupted railway traffic for several months.

In another instance the obstruction to the flow of flood water caused by the erroneous placing of piers caused the loss of part of that bridge, injury to others, and loss of life.

The state should have authority to do more than specify the width of draw in a bridge.

No applications have been presented for approval since the last report.

Bridges on Interstate Streams. The Department of Engineering has recently been brought into contact with the subject named at the head of this paragraph. The legislature appropriated $25,000 as the state's share of the cost of constructing a bridge across the Colorado River connecting Needles in California and Topock, Arizona. The Colorado River is the boundary between the two states at this point, and an Indian reservation occupies one bank of the stream.

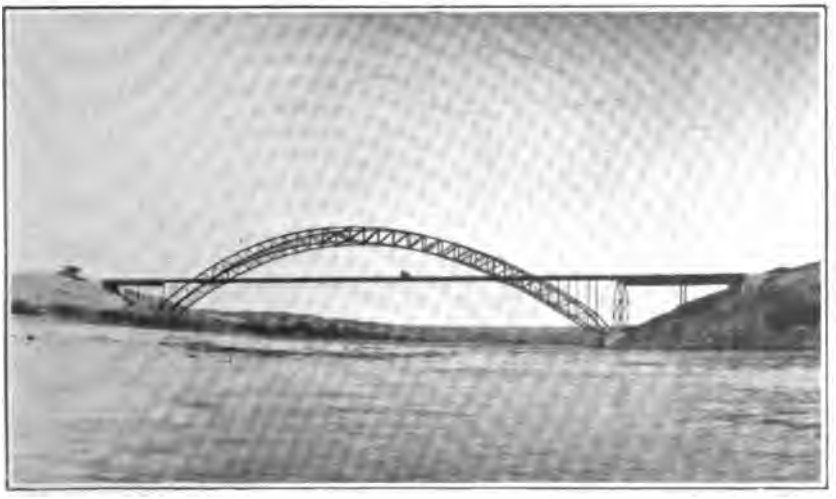
The two states and the United States Indian Service cooperated in the construction of the bridge and under the terms of the agreement each state is responsible for the maintenance of the approach and that part of the bridge on its side of the center line of the river. While California assumes responsibility for maintenance of the west half of the bridge, that duty is placed upon San Bernardino County by the terms of the appropriation act.

The bridge was designed by J. A. Sourwine, county surveyor of San Bernardino County. The designs were checked and slightly altered by the Department of Engineering, and the construction was executed under the direction of the Indian Service.

The bridge is quite a striking structure, being the longest three-hinged arch bridge in the United States.

PLATE XVII.

Interstate highway bridge over Colorado River below Needles, during construction.



Interstate highway bridge over Colorado River after completion.

SURVEY OF RESERVOIRS.

The growing importance of water storage in connection with irrigation, flood control, navigation and power production brings nearer the time when accurate knowledge must be had of all the storage possibilities existing.

The Department of Engineering is keenly alive to the importance of the subject and loses no opportunity to obtain information upon the subject, and is gradually accumulating data regarding location of possible reservoir sites, the size of dam required, capacity of reservoir and probable supply.

There is a popular belief that unlimited opportunities exist in the mountains for the storage of water, and that if they were utilized destructive floods would be prevented, and the waters be made available for use when the flow has diminished or ceased.

Investigation has shown that that belief is largely in error. Many good reservoir sites exist which can be utilized and which will render great aid in all of the ways mentioned, by reducing the critical flood peak, and by furnishing water late in the season for the various purposes requiring it at that time, but unfortunately when all practicable sites shall have been occupied their combined influence will fall far short of exercising the degree of control desired. To cite a case in point:

Upper Pit River Basin. Several years ago, a reconnaissance had discovered several basins in the territory drained by Pit River which appeared to offer opportunity for storage reservoirs. Surveys showed that four reservoirs could be created having a combined capacity of more than 4,000,000 acre-feet, and the sites were withdrawn from sale or entry pending the time when they could be devoted to public use. A considerable part of the land within the withdrawn areas had already passed to private ownership.

Years elapsed and no action was taken toward utilizing the sites and acquiring the lands privately owned. This condition created dissatisfaction, since a landowner could not dispose of his holdings and give a title guaranteed to remain undisturbed. So great did the dissatisfaction become that a bill was introduced in congress to restore all of the sites to public domain.

The Department of Engineering, feeling that no available reservoir site on public land should be restored to entry where it could, and if valuable would, be acquired to private ownership, effected a cooperative arrangement with the United States Reclamation Service and a survey was made, not alone of the four sites named, but of six others which had been represented as offering desirable advantages.

At the time the withdrawals were made there was no record of the

quantity of water available to store in proposed reservoirs, but records of stream flow in the Pit River Basin have since then been obtained.

The result of the cooperative survey mentioned and study of the run-off records showed that a dam 100 feet high at the outlet of Big Valley would create a reservoir capable of holding 3,200,000 acre-feet of water. A dam 70 feet high at Warm Springs Valley would store 560,000 acre-feet. The capacity of a reservoir in Round Valley with a dam 100 feet high would be 185,000 acre-feet, while a 100-foot dam at Jess Valley would create 245,000 acre-feet of storage. The storage capacity of these four sites with a maximum height of dam of 100 feet aggregates 4,190,000 acre-feet, while the average annual flow at the Big Valley dam site is estimated to be 429,000 acre-feet.

At that rate it would require eight and one-third years to fill the reservoir, not allowing for evaporation losses, even if none were withdrawn for use and none stored in the other reservoirs.

The conclusions reached, as a result of the surveys and studies made, is that only two of the ten sites examined are practicable for storage. Round Valley has possibly 70,000 acre-feet a year available for storage and Jess Valley 50,000 acre-feet, making a total of 120,000 acre-feet of water that it is practicable to store in the basin above Big Valley, which amount would be deducted from the quantity estimated as reaching Big Valley site, leaving but 309,000 acre-feet, or less than one-tenth the capacity of that reservoir, available for storage.

The net result of the investigation was the abandonment of Big Valley site and all others, excepting Round Valley and Jess Valley, and the elimination of their 4,000,000 acre-feet of storage capacity, from all future calculations of storage in the Upper Pit River Basin.

The sites thus eliminated as probable factors in irrigation development of Upper Pit River Basin are:

Big Valley,	Big Sage,
Warm Springs Valley,	West Valley,
Delta Lake,	Widow Valley,
Crooks Canyon,	Ash Creek Valley.

Lower Pit Basin. The survey described above considered four sites in the drainage basin of Pit River below the Big Valley dam site. Two of these, Dixie Valley and Little Valley, are on Horse Creek, which enters Pit River about twelve miles below Big Valley. A third, at Great Spring, is located on Hat Creek, which joins the river near Carbon, some ten miles below the confluence of Fall River.

PLATE XVIII.

Hope Valley reservoir site, Carson River.

Reservoir site, Calaveras River.

The elements of these sites are as follows, the capacity stated being the estimated quantity of water available:

	Dam		Capacity, acre feet
	Bottom length, feet	Height, feet	
Dixie Valley	100	50	25,000
Little Valley	100	70-100	30,000
Great Spring	250	75 100	80,000 100,000

Most of the irrigable lands in the vicinity of these sites are already served without resort to storage, and as the nearest lands to be irrigated from water stored here are a hundred miles away, it does not appear that small reservoirs in this region are economically feasible at this time.

The fourth site considered embraces the valleys of Pit and Fall Rivers above their confluence. Here a dam 115 feet high would store about 750,000 acre-feet of water, and as the mean annual flow at this point is estimated to be 1,000,000 acre-feet, so far as the water supply is concerned a reservoir here is feasible. The cost of a reservoir here is quite low, being estimated as ranging between $7 and $8 an acre-foot. Notwithstanding the advantages of plentiful water and low cost, there are disadvantages that seem to remove the Fall River reservoir from consideration on economic grounds, at least for some time to come.

Surrounding the site is a vast territory of rugged mountain slopes, more or less covered with timber and affording grazing ground for immense herds of cattle. The usefulness of this great range would be greatly reduced if it were not that in the little valleys dotting it here and there hay enough is raised to feed the cattle during the winter months when the range is covered with snow.

The creation of the Fall River reservoir would destroy 50,000 acres of the best hay and grain land in the Pit River Basin. The economic value of these lands to the cattle industry of the surrounding country is so great that their use for reservoir purposes would not be justified under present conditions. The reservoir would be of little value as a factor in flood control, since the disastrous floods of the Sacramento River originate below the drainage basins tributary to the reservoir.

Iron Canyon Project. For many years it has been the dream of people interested in the development of the Sacramento Valley that some day a large area of the valley would be irrigated from the waters of Sacramento River stored in a reservoir in Iron Canyon near Red Bluff.

The government caused preliminary investigations to be made in 1904 and 1905 and following a visit to the site by Secretary of the Interior

J. R. Garfield, the studies were resumed in 1909 and a partial report rendered thereon. To further the project the Iron Canyon Project Association was formed, which in 1913 effected arrangements with the United States Reclamation Service for a complete investigation, the association furnishing a part of the funds. The investigation was conducted under the direction of Mr. E. G. Hopson, supervising engineer of the Reclamation Service. Upon the completion of the report Honorable Franklin K. Lane, Secretary of the Interior, appointed a board to consider the investigations of the Iron Canyon project and to report thereon.

The board of review appointed was composed of the following: Brigadier General W. L. Marshall, formerly Chief of Engineers, U. S. Army, and consulting engineer to the Secretary of the Interior, Chairman; W. F. McClure, State Engineer of California; D. C. Henney, Acting Chief Engineer, U. S. Reclamation Service, and H. T. Cory, Consulting Engineer, representing individual and corporate interests that would be affected by the project.

The report was dated October, 1914, and presented a very comprehensive plan for the irrigation of a large body of land at the head of the Sacramento Valley. A tract of 270,000 acres was selected, lying mainly on the west side of the river between Red Bluff and Willows. A tract of 10,000 acres on the east side of the river opposite Red Bluff was included in the project. The report does not assume that the tracts selected are the only lands susceptible of irrigation under the project nor that 270,000 acres is the maximum area that may be finally brought into the scheme.

The plans presented contemplate the construction of a dam in Iron Canyon, with appurtenant structures to serve different purposes, and a system of delivery canals to convey the water to the lands to be irrigated.

Three different sized reservoirs are considered, which are presented with their characteristics in the following table:

Storage at Iron Canyon Reservoir.

Height of dam	Capacity, acre feet	Cost of reservoir	Cost of storage per acre foot
110 feet	231,000	$4,325,000	$18 75
123 feet	420,000	5,000,000	11 90
132.5 feet	603,000	7,575,000	12 56

The cost of a canal system to deliver the water to the lands would be the same in either case and must be added to the cost of the reservoir to obtain the total cost of the project.

Several alternative plans enter into the figures of cost above presented, all based upon the irrigation of 225,000 acres of land, but with the works designed with consideration of other purposes also.

It is conceded that works of the magnitude of the proposed project will have a marked influence in the solution of the several problems of irrigation, navigation, flood control and power development, and all of these matters were considered in presenting several alternative plans.

In the designs three basic features are kept in view, viz:

I. 225,000 acres of land to be irrigated. Canal system to cost $8,400,000.

II. Navigation as conducted on the Sacramento River, requires a minimum flow of 4,750 second-feet at Iron Canyon.

III. The flood flow in the river has reached a maximum of 254,000 second-feet at Iron Canyon, and the river channel below is not capable of carrying more than 100,000 second-feet without overflowing its banks.

The several plans presented involve the following considerations:

1. Irrigation without storage; no dam; comprehensive river work to compensate for low water withdrawn, costing $4,000,000. Total cost ---------- $16,325,000
2. Same as No. 1, omitting river work. Total cost ------ 12,325,000
3. Dam and partial storage; river flow reduced to 3,700 second-feet; river improvement to cost $1,500,000. Total cost ---------- 14,200,000
4. Same as No. 3, but adding provision for 50,000 horsepower development. Total cost ---------- 15,950,000
5. Same as No. 3, but omitting river improvement. Total cost ---------- 12,700,000
6. Same as No. 4, but omitting river improvement. Total cost ---------- 14,450,000
7. Dam and storage; no reduction of river flow. Total cost 13,400,000
8. Same as No. 7, but adding provision for 60,000 horsepower production. Total cost ---------- 15,450,000
9. Same as No. 7, but adding provision for flood control, limiting flood flow to 100,000 second-feet. Total cost 15,975,000
10. Dam and storage; no interference with navigation flow; flood control limiting flood flow to 100,000 second-feet; provision for 70,000 horsepower development. Total cost ---------- 18,785,000

Other reservoirs in Northern California. Data of reservoirs obtained by reconnaissance for irrigation district or other enterprises in the Sacramento River drainage basin are on Last Chance Creek in eastern Plumas County and in Butte County.

Honey Lake Valley Reservoirs. Records have been obtained concerning the following proposed reservoirs in the drainage basins tributary to Honey Lake:

	Height of dam	Capacity, acre-feet
Baxter Creek	52	13,000
Warm Springs, Long Valley	130	93,000
Red Rock Valley	110	35,000

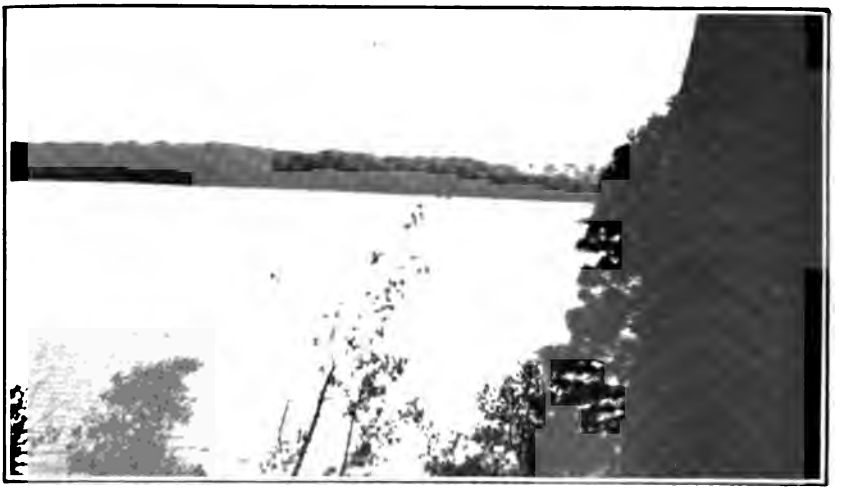
San Joaquin River Basin. Data have been obtained concerning two reservoir sites on Kern River, one each on Kaweah, Kings and Calaveras rivers and two on Cosumnes River, none of which had been recorded heretofore.

Reconnaissances were made of another on Kings, and one on San Joaquin River.

While the data concerning the possibility of storage at the places named have not been analyzed, and much of it not verified, still it will be valuable in studies of flood control and navigation as well as of irrigation.

PLATE XIX.

Dam, McCoy Flat Reservoir, Susan River.



Bidwell Lake, Lassen County; Cinder Cone in distance.

SAN FRANCISCO HARBOR FRONT.

The harbor front of the city of San Francisco is state property and is administered by a Board of State Harbor Commissioners, which has jurisdiction over the construction, operation and maintenance of the docks, wharves, buildings and appurtenances of every kind. The board reports directly to the Governor.

All engineering, including design and construction, is by law placed in the Department of Engineering, and is exercised through a chief engineer of the Board of Harbor Commissioners appointed by the department.

Mr. Jerome Newman occupied that position until June 30, 1916, when he resigned and was succeeded by Mr. Frank G. White.

Mr. Newman's report, made to the Harbor Commission at the close of his term, is here presented:

REPORT OF CHIEF ENGINEER, SAN FRANCISCO STATE HARBOR COMMISSION.

By JEROME NEWMAN, Chief Engineer.

Herewith I beg to submit my report as chief engineer of your board, for the term beginning July 1, 1914, and ending June 30, 1916.

As mentioned in my biennial report for the term ending June 30, 1914, there were under construction on the latter date the following structures, which are described in the report:

Section A of the seawall which was 76½ per cent completed.

Section 9 B of the seawall for which a contract had been awarded, but on which work had not begun.

Pier 46, which was 46 per cent completed.

Pier 41, which was 21 per cent completed.

Pier 15, which was 6 per cent completed.

Repairs to Pier 19, which were 12 per cent completed.

Belt Railroad extension to United States Army Transport Docks at Fort Mason, which was 47 per cent completed.

Car ferry slips, which were 4 per cent completed.

Sewering and paving the southerly half of Bryant street between Main and Spear streets and the easterly half of Spear street from The Embarcadero to near Harrison street.

Sewering and paving The Embarcadero from Pier 34 to Pier 26, which was 2 per cent completed.

All of these contracts have been completed and the structures placed in service.

The various subdivisions of the work of the Engineering Department will be reported on separately, as follows:

1. Construction, piers and wharves.
2. Maintenance and repairs.
3. Belt Railroad.
4. Ferry slips and buildings.
5. Street work and maintenance.
6. Electrical department.
7. Dredging.
8. Testing department.

1. Construction.

Piers and bulkhead wharves.

Besides contracts for the construction of several new piers, a number of others were let for additions and improvements to existing structures in connection with repairs which were necessary to place them in good condition. The new piers are numbered 24, 22, 18, 16, 29, 35 and 37; the piers to which additions and improvements were made being numbered 44, 38, 12 (new number 20), 9, 13 (new numbers 7 and 11), 21.

New piers and extensions to existing piers.

Pier 24. This pier is 127 feet wide with a length of 800 feet. The substructure is creosoted piles, supporting a timber deck covered with asphalt in the cargo space and outside the shed, with a pavement of wood blocks in the driveway. There is a depressed track on the northerly side.

The shed is of timber, 98 feet wide by 790 feet long, with rolling steel doors, and has an elevated gallery for the use of passengers. The fender line is creosoted piling protected by untreated Oregon pine sheathing.

As in the case of all piers built in the last two years, the shed has an ornamental front, extending over and along the bulkhead, constructed of timber covered with cement plaster. This bulkhead building is 44 feet deep by 130 feet long.

Pier 24 was completed in September, 1915.

Pier 22. This pier is 125 feet wide by 407 feet long, the length being determined by the depth of water at the outer end; it is expected that the shoaling consequent on the construction of the piers in this vicinity will permit of its being lengthened in a few years, if required.

The substructure is creosoted piles with a timber deck covered with bituminous concrete and with a wood block driveway. There is a flush track on the northerly side. The fender line is similar to that on Pier 24.

The shed is timber, 100 feet wide by 395 feet long with a bulkhead building 44 feet deep and 130 feet long built of wood covered with cement plaster.

Pier 22 was completed in March, 1916.

Pier 20 Extension. In connection with the construction of Piers 16 and 18, it was decided to lengthen Pier 20 (old number 12) in order to afford more berthing and storage space. A portion of the inner end of this pier had been removed to make room for the construction of Section 9 B of the seawall and after the extension had been completed the inner end was rebuilt and a new bulkhead building added of timber covered with cement plaster, uniform with the structure in front of Piers 16 and 18.

The extension is 111 feet wide by 72 feet long, with a creosoted pile substructure and wooden deck and driveway. The flush track on the northerly side was extended with the pier.

This extension was completed in December, 1915.

Piers 16 and 18. Although built under separate contracts, these piers may be considered as one structure, as they are similar in plan and have a continuous bulkhead building between them and extending to the southerly side of Pier 20.

Each pier is 140 feet wide by 686 feet long, and has a creosoted pile substructure carrying a wooden deck covered with asphalt, except in the driveway which is paved with wood blocks, and is provided with two tracks, the northerly one being depressed and extending the entire length of the pier and the southerly one being a short flush track. The fender line is the usual creosoted pile type with untreated Oregon pine protection.

The piers are arranged for convenient handling of coastwise freight and passengers in conformity with the wishes of shipping men. There are side aprons for handling freight, and elevated landing bridges leading to galleries for the use of passengers.

The sheds are timber, 101 feet wide by 680 feet long, with steel rolling doors. As mentioned above, there is a continuous bulkhead building, 41 feet deep by 773 feet long from the northerly side of Pier 16 to the southerly side of Pier 20, containing work rooms, waiting and baggage rooms and offices of the company to which the piers are assigned.

Pier 16 was completed in May, 1915, and Pier 18 in June, 1915.

Pier 29. This pier is 200 feet wide by 800 feet long. The inner 600 feet is supported on reinforced concrete piles, the outer 200 feet on account of the depth of mud, on concrete cylinders resting on timber piles. The deck is of the usual transverse girder, longitudinal beam and slab type covered with asphalt, except in the driveway, which is paved with wood blocks. There are two tracks, one on each side, the northerly one being depressed and the southerly one flush. The fender line is creosoted pile with untreated Oregon pine sheathing.

In addition to the pier, the contract included the construction of a section of reinforced concrete bulkhead wharf, 44 feet wide and 608 feet long, extending each side of the pier. This bulkhead wharf is similar in type to that described in connection with Pier 39 in the last biennial report.

Plans for a shed are being prepared and will be ready for contract when the pier is completed.

Pier 29 was 68 per cent completed June 30, 1916.

Pier 35. This pier is 200 feet wide, with an average length of 896 feet. The substructure is reinforced concrete piles, carrying a reinforced concrete deck covered with asphalt, except in the driveway which is paved with wood blocks. The northerly one of the two tracks is depressed, the southerly one flush. The fender line is similar in construction to that on Pier 29.

The construction of Piers 35 and 29 presented some interesting problems in casting and driving reinforced concrete piles. The plans as originally prepared, called for 92-foot piles at the outer end, but before reaching this point it was found that the unfavorable foundation required the use of longer piles and it was decided to substitute piles 106 feet long, 20 inches square and reinforced with eight one-inch bars. These very long and heavy piles, weighing 23 tons each, were successfully handled and driven and are believed to be the longest piles of this kind ever used.

The shed is timber, 160 feet wide and 900 feet long, covered with asbestos-protected metal, which material was selected on account of its fire-resisting qualities, and is fitted with steel rolling doors. There is a bulkhead building in front of the shed, 33 feet deep and 316 feet long, constructed of timber covered with cement plaster.

The contract for the pier included a section of reinforced concrete bulkhead wharf, 45 feet wide and 494 feet long, similar in type to that built at Pier 29.

Pier 35 was completed in June, 1916.

Pier 37. This pier is 200 feet wide with an average length of 937 feet. It has a creosoted pile substructure carrying a wooden deck covered with asphalt, with a wood block pavement in the driveway. There are two tracks, the northerly one being depressed, the southerly one flush. The fender line is of the standard creosoted pile type, similar to those on Piers 29 and 35.

The shed is timber, 160 feet wide and 940 feet long, provided with steel rolling doors. There is a bulkhead building 33 feet deep by 348 feet long, of timber covered with cement plaster.

The contract for this pier also included the construction of a reinforced concrete bulkhead wharf 45 feet wide and 607 feet long of the same design as that used at Pier 29.

Pier 37 was completed in June, 1915.

Additions to existing piers.

Pier 44. In connection with the repairs to this pier, which will be described under "Maintenance and Repairs," a new bulkhead wharf building 32 feet deep and 147 feet wide is to be constructed. This building is to be of timber, covered with cement plaster.

This addition was 5 per cent completed on June 30, 1916.

Pier 38. The center track originally built on this pier having proved unsatisfactory, it was decided to replace it by a depressed track on the northerly side. This required the construction of an addition 20 feet wide and 540 feet long, supported on creosoted piles, carrying a timber deck, covered with a seal coat of hot asphalt and coarse sand, and having the standard creosoted pile fender line.

This addition was 2 per cent completed on June 30, 1916.

Pier 7 (old number 9). In connection with the repairs to this pier, a new bulkhead wharf building, 30 feet deep and 300 feet long, was constructed; this is timber covered with cement plaster. To adapt the pier for coastwise traffic, new cargo aprons, passenger bridges and an elevated gallery were also added.

A reinforced concrete bulkhead wharf, 44 feet wide and 363 feet long, was built under the same contract as the bulkhead wharf building; this wharf is of the same type as the one at Pier 29.

The addition to Pier 7 was 83 per cent completed on June 30, 1916.

Pier 11 (old number 13). Under the contract for repairing this pier, extensive additions were made, consisting of an extension to the shed, a bulkhead wharf building, a depressed track on the northerly side and a section of reinforced concrete bulkhead wharf.

The old shed, which covered only the outer half of the pier, was extended over the inner half for 416 feet, and a timber bulkhead wharf building 30 feet deep and 126 feet long, covered with cement plaster, was added.

The addition for the depressed track is 18 feet wide and 800 feet long; the substructure is creosoted piling, carrying a timber deck covered with bituminous concrete.

The concrete bulkhead wharf is 44 feet wide and 363 feet deep, and similar in design to the one at Pier 29.

These additions were 50 per cent completed on June 30, 1916.

Projected work.

Plans for new work are in course of preparation as follows:

Track and addition to Pier 40, to replace the present center track; these are 90 per cent completed.

Pier 3, to replace present Pier 5, with adjacent bulkhead wharf, 50 per cent completed.

Bulkhead wharf buildings at new Pier 3; these are 30 per cent completed.

Shed on Pier 29: these are 5 per cent completed.

Pier 31, north of Pier 29; these are 10 per cent completed.

Bulkhead wharf between Piers 29 and 31; these are 5 per cent completed.

Bulkhead wharf buildings at Piers 29 and 31; these are 10 per cent completed.

Shed on Pier 29; these are 5 per cent completed.

Extension of southerly dolphin of car ferry slips; these are completed and ready for contract.

2. Maintenance and Repairs.

In accordance with the practice of the board, the ordinary repairs to piers, wharves and slips have been made by the state force. Several contracts were let for large repair jobs on various piers, together with additions to these structures, which latter have been described under the head of "Construction."

The piers to which repairs were made by contract are Nos. 44, 7 (old number 9), 9 (old number 11), 11 (old number 13), 19, 21, and 23. Of these, Nos. 44, 7, 11, 13, 19, 21 and 23 are concrete cylinder piers, built by the old method of depositing concrete in water, and were in bad condition. The repairs to these piers were made by taking down and removing the defective cylinders and replacing them with creosoted piles which will insure a further useful life of about 15 years. Pier 9 is a creosoted pile structure and the repairs were made by driving the necessary new piles.

In all cases, the decks were repaired at the same time as the substructure and, where possible, were covered with asphalt or bituminous concrete.

The cylinders supporting the main and side aprons in ferry slips 1 and 2 were examined by divers and found to be in a dangerous condition. These cylinders were of the old type and plans for replacing them with concrete piles have been completed and arrangements made to have the work done partly by state forces and partly by contract.

The steel rolling doors on piers constructed some years ago are in need of repainting and contracts are to be let for cleaning and repainting them as opportunity offers.

3. Belt Railroad.

Owing to the increased mileage and consequent large amount of traffic on the Belt Railroad, the work of maintenance has become heavier and the tracklaying force has been busily employed. In addition to ordinary maintenance, numerous turnouts have been laid to new piers and new tracks built on existing piers when requested by the tenants. As mentioned in the last report, all piers of sufficient width are provided with two tracks, one surface and one depressed, those not wide enough for two tracks having only one. Latterly the occupants of piers have shown a decided preference for depressed tracks and it would seem that this type be considered standard, to be departed from only on the request of the user.

The extension to the Transport Docks was completed October 29, 1914, and has been rendering good service since that date. The federal government is considering an extension of this line and negotiations for right of way have been begun.

4. Ferry Slips and Buildings.

Passenger slips 7, 9 and 10, described in the last report, were completed, as planned, in January, 1915.

The car ferry slips, also described in the last report, were completed in December, 1914.

The buildings described, viz: Ferry Building extension, Post Office, and Wells Fargo & Company's building have also been completed as follows:

Ferry Building extension, in February, 1915.

Post Office, in August, 1915.

Wells Fargo & Company's building, in May, 1915.

The Ferry Building extension, which contains baggage rooms used by the Southern Pacific and the Western Pacific, was very useful during the exposition period in taking care of visitors, and the Post Office now handles practically all mail for the business section, saving time in collection and delivery and expense in distribution.

In addition to the buildings enumerated above, several others have been constructed for various purposes as follows:

A fire house for the use of the San Francisco Fire Department, located on the bulkhead wharf between Piers 22 and 24. This is a two-story timber building, 38 feet by 62 feet in size, covered with cement plaster and containing a garage for a motor drive engine, with living and sleeping rooms for the company. This building was completed in April, 1915.

A building for the use of the launch companies, located on the bulkhead north of Pier 16 and containing storerooms and offices. This building is 20 feet by 164 feet in size, is constructed of timber and covered with cement plaster. It was completed in March, 1916.

A small ticket office for the Southern Pacific Creek Route ferry, 21 feet by 30 feet in size, of timber covered with cement plaster. This was completed in January, 1916.

A timber shed for the American Express Company on the dolphin between Slips 9 and 10. The front portion is 60 feet by 100 feet, the rear 65 feet by an average width of 82 feet. This was completed in August, 1915.

5. Street Work and Maintenance.

On account of the increase in vehicular traffic during the last two years, the paving force has been extremely busy on repair work. In addition to this, a considerable amount of new work has been done by contract as follows:

Sewering and paving the southerly half of Bryant street between Main and Spear streets, and the easterly half of Spear street from The Embarcadero to near Harrison street, mentioned in the last report. This was completed in November, 1914.

Sewering and paving The Embarcadero from Pier 34 to Pier 26, also mentioned in the last report. This was completed in September, 1914.

Paving the approaches to The Embarcadero on Main and Fremont streets; completed in November, 1914.

Laying an asphalt sidewalk from Pier 3 to Pier 13; completed in December, 1914.

Paving Jefferson street between Leavenworth and Hyde streets; completed in April, 1915.

Paving that portion of The Embarcadero between Market and Folsom streets reclaimed by the construction of the seawall, and laying a concrete sidewalk to south of the Post Office. To provide for settlement, the pavement was constructed of bituminous macadam, the intention being to replace it with permanent material when the subsidence has stopped. This work was completed in December, 1915.

Paving The Embarcadero between Brannan and Harrison streets; completed in February, 1916.

Laying an asphalt sidewalk on the east side of Sansome street, between Lombard and Chestnut streets; completed in January, 1916.

6. Electrical Department.

The electrical department during the past two years has been continuing the work of extending the underground system of state wires, both for lighting and signal purposes.

The electric lighting system along The Embarcadero has been extended from Pier 22 northerly to the Ferry Building and from Pier 27 northerly to the car ferry slips at the foot of Mason street; 25 additional electroliers have been installed between Pier 22 and the Ferry Building, and 30 are being placed north of Pier 27. When the installation of the latter is completed, there will be a continuous line of high efficiency electroliers, 140 in number, from Channel street to Mason street, directly controlled from the central switchboard in the Ferry Building.

Pier illumination has been greatly improved by the substitution of the new nitrogen lamp for the old style Mazda type, and Piers 24, 22, 20, 18, 16, 9, 35 and 37, the Post Office, Wells Fargo & Company's building, American Express Company's office, launch offices and the fire house have been wired.

The lighting of the Ferry Building, which was quite unsatisfactory, has been bettered by the introduction of a system of indirect lighting, which has also been installed in the Post Office and other buildings in the vicinity.

The underground conduit system for Harbor Commission wires, which is planned between Channel and Mason streets, has been extended to Pier 11 from Harrison street; conduits are now being placed in sections 2 and 3 of the seawall, and the section from Pier 11 to Mason street is about 75 per cent completed.

In conformity with plans adopted some years ago, all poles and overhead wires, with the exception of those owned by the street railroads, have been placed underground.

Twenty-two new fire boxes have been authorized and are being installed on The Embarcadero; these are connected with the fire alarm system of the city.

A new system of 39 fire alarm boxes has also been installed in the Ferry Building and is to be connected with the city's system.

The remote control system has been enlarged to include all street and pier lighting between Channel and Mason streets.

Tugs and dredgers.

Besides the routine work of dredging, this department has been engaged in pulling piles at the sites of new piers before and after completion.

As mentioned in the last report, the equipment, owing to its age, entails excessive cost of maintenance, which is growing larger yearly, and the time will soon arrive when as a matter of economy its replacement should be considered. This is particularly the case with scows at present in use, some of which are 30 years old and have been in service continuously.

Testing department.

Since the last report, the testing laboratory has increased in size and equipment. The installation of the 150,000-pound machine has rendered possible the physical testing of all structural metals, concrete, brick, etc., in addition to which the local shop inspection of structural steel has also been handled.

An important part of the work of this department has been the investigation of asphaltic cements, asphaltic concrete, prepared roofing, saturated felts and paints

for structural steel, wood and concrete. The work of the department along these lines has saved the state many thousands of dollars and it would be extremely unwise to curtail this work, as proposed, by the reduction or elimination of the force employed.

In addition to the regular work of the Harbor Commission, numerous tests have been made for the State Department of Engineering and the Highway Commission, these tests have been made without charge, and have been of material assistance to the two departments.

IRRIGATION.

Irrigation is defined as the watering of land by artificial means to promote the growth of agricultural crops.

It is one of the oldest arts of man, antedating historical records, as evidenced by the remains of irrigation works in Asia, Africa and the Western Hemisphere. Modern canals in Mesopotamia utilize portions of old conduits believed to have been irrigating canals used in the days when Adam was condemned to "eat bread in the sweat of his face."

Irrigated lands are usually fertile, and irrigation tends to intensive cultivation. In Italy 800 people to the square mile live and draw their sustenance from irrigated lands. In Egypt 900, and in parts of India 1200 are supported on a square mile.

Modern irrigation in California dates back nearly 150 years to the founding of the missions by Junipero Serra and his intrepid compatriots; the ruins of whose works testify to the energy and versatility displayed by those wonderful men.

Evidence also exists which indicates that irrigation had been attempted long before the coming of the padres. In Kern and Tulare counties are old ditches in the bottoms of which large oak trees, centuries old, are growing. When white people discovered them, the oldest Indians had no traditions concerning their builders. Nor do the records of the missions show that any settlements ever were made by the Franciscans in the far interior.

Speculation suggests that possibly a Spanish galleon voyaging from the Philippines some time in the sixteenth century, being chased from its course by an English privateer, was wrecked on the coast. The crew might have wandered inland and attempted to establish irrigation as it was practiced in the fatherland. This theory is strengthened by the fact that in the early days of white settlement, in the country about the old ruins, many articles were found, such as sword-blades, spear heads and knives, of Spanish manufacture, and crude homemade spurs of Castilian pattern.

When irrigation was introduced into California will probably never be known, but its effects on production of the necessaries and luxuries of life are recognized the world over.

In all the countries of the world which keep records of such things (excepting China) there are said to be 100,000,000 acres of land[1] susceptible of irrigation, of which 45,000,000 acres are in the United States.

According to a census taken in 1912 for the California Conservation Commission the state contains about 21,000,000 acres of tillable land

[1]Nelson's Encyclopedia.

that would be benefited by irrigation if water could be obtained and applied.

The records of stream flow indicate that the annual run-off of water from all the streams in the state aggregates 60,000,000 acre-feet, or nearly three acre-feet of water for every acre of irrigable land.

But, unfortunately, only a small portion of that large quantity can be made available. Most of the run-off is in winter and spring floods, at such times when the lands do not need the water, and in such quantities that only a small part could be diverted for use if the lands were ready for it.

It is estimated that about 11,000,000 acres of irrigable lands can be irrigated at a cost not prohibitive, and it is not improbable that when all of this land is brought under cultivation, scientific methods will enable a given quantity of water to efficiently serve a larger area than now obtains.

By scientific methods is meant, not alone the application of science in methods of procuring the water, of storing it, and of conveying it long distances, without unnecessary loss—not only scientific methods of applying water to the lands in the proper quantities at the right times and in the correct way to get the greatest benefits; but science will teach, as well, the kinds of crops and the best way to manipulate the soils so as to conserve the moisture.

"Brain and brawn" must be used with the water in its application before the fruits of irrigation shall be harvested to their uttermost fullness. When it is known that a community has a fixed and limited quantity of water for its lands, it must learn what kind of crops will give the best returns for that amount of water, and no one must be permitted to cultivate other crops which demand a larger quantity.

When it is known that vigorous stirring of the soil will conserve the water applied in irrigation by preventing evaporation, the area served can be extended to the extent that the water is saved from evaporation.

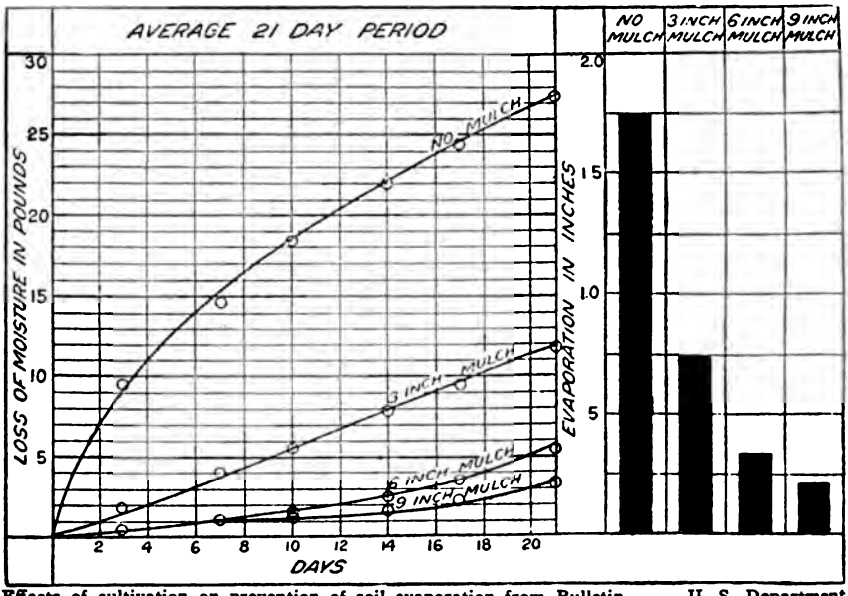
Experiment has shown that where water was applied to soil to the depth of six inches and the soil left untouched after the water was absorbed, the loss by evaporation in three weeks amounted to one and three-fourths inches, or nearly 30 per cent. When the surface of the soil was stirred so as to produce a mulch three inches deep the evaporation was three-fourths of an inch, or 12½ per cent of the water applied, and when the mulch was nine inches in depth the loss from evaporation amounted to only four-tenths of an inch of water or less than 7 per cent of that applied. The conclusions deduced from the experiments are:

1. A dry, granular mulch three inches deep will save, other conditions being equal, at least one-half of the loss from an unmulched surface.

2. A like mulch six inches deep, will save 75 per cent of the evaporation from an unmulched surface.

3. In comparing the efficiency of a six-inch mulch with a nine-inch mulch, the result shows a considerable saving in water by the deeper mulch, but the cost of cultivation and other practical considerations would seem to limit the depth to six inches or less.

The following figure graphically illustrates the loss occurring from evaporation as just described.



Effects of cultivation on prevention of soil evaporation from Bulletin ——, U. S. Department of Agriculture.

But this is not the only preventable loss. Ditches excavated in broken rock and absorbent soil lose a large part of the water carried by them. Different degrees of porosity, of course, affect the amount of loss from percolation. In some cases in mind, where the water is conveyed several miles in side-hill ditches, it is found that when only 100 second-feet of water is available at the head of the ditch the loss between that point and the nearest point of use is 100 per cent. That is to say, all is lost and unless more than the quantity stated can be turned in no attempt is made to take any.

Government investigators have reported that the average losses of water in its application for irrigation was 60 per cent, and not infrequently only 20 per cent of that delivered to the land was usefully applied.

With 20 to 50 per cent of the water diverted lost in transmission through leaking conduits, 60 per cent of that reaching the lands wasted by wrong methods of application and 30 per cent of that correctly applied being lost by preventable evaporation, aggregating a total loss of 80 per cent and leaving only about 20 per cent of that diverted to

be utilized in support of plant life it is plainly seen that much remains to be done by conservation.

Storage of waste flood waters, conveying them in nonleaking conduits, economical application to the soils, selection of crops best adapted to the conditions, and thorough cultivation to reduce evaporation, all will conduce to the great extension of irrigated areas with the waters available.

Several agencies, federal and state, are engaged in research with a view of some day bringing the water to the land and getting the most out of it.

It is known that many opportunities exist for storing waste waters, and these are being examined, measured and catalogued as opportunity and funds permit. In many localities are underground stores of water. Their extent and availability, as well as means of increasing them, are being studied as extensively as means are provided.

These investigations are being conducted by the Department of Engineering and other agencies of the state, acting alone or in cooperation with various departments of the national government.

The state and government cooperate in experiment and investigation into the matters of applying water for irrigation and its effects on different crops. The reports upon these matters are published from time to time as bulletins and in the aggregate contain a vast amount of valuable information.

IRRIGATION DISTRICTS.

The gradual decline of wheat farming on the dry plains, with a demonstration in a few favored spots of the benefits to be had from irrigation, stimulated a desire on the part of homesteaders to irrigate their lands. But to build diversion dams and long canals is expensive and wholly beyond the financial ability of the individual farmer to accomplish.

The need for some method of cooperation led to the enactment in 1887 of the so-called Wright Irrigation District Law. Under this law many districts were formed. Many of them were meritorious, but most were created without knowledge of the elements necessary to success. Some were speculative—"wildcat" schemes, pure and simple.

The administration of the act was beset by many difficulties and led to prolonged and costly litigation. Practically every provision was attacked in the courts and some of the cases were carried to the highest courts of the nation for decision.

In 1897 the Bridgeford act was passed, embracing the best parts of the old Wright act and other provisions which the court decisions and experience had shown to be desirable. From the passage of the original Wright act, March 7, 1887, great activity was manifest in cooperative

attempts to extend irrigation. Within eight years 49 districts were organized. The years of greatest activity were 1890 and 1891 when 11 and 13 districts, respectively, were brought into being.

The 49 districts embraced more than 2,000,000 acres of land, and the several districts voted an aggregate of upwards of $18,000,000 in bonds with which to finance their several schemes.

That the proponents of irrigation under the district system were overzealous is shown by the fact that only nine of the entire number formed succeeded in maintaining and operating their organizations.

The various causes which led to the nonsuccess of the districts is clearly set forth in a history of irrigation districts compiled by Frank Adams, irrigation manager, Office of Public Roads and Rural Engineering, United States Department of Agriculture, and published early in 1916 by this department as Bulletin No. 2.

The demand for the little volume was so great that the issue was quickly exhausted and to meet the frequent requests for copies it is herewith reprinted as Appendix B to this report. A perusal of this history is commended to the student of cooperative effort for industrial development.

As stated above, only nine of the districts created under the Wright act survived, and the struggles of eight of them to live through the years of adversity were nothing short of heroic. The one lone exception was Walnut District in Los Angeles County, containing 870 acres. It acquired an existing ditch system which it has continued to successfully operate without resort to a bond issue.

Some of the other districts never progressed to the point of issuing bonds. Others voted bonds in varying amounts, from $3 to $88 an acre. It is said that not one of those issuing bonds but at some time defaulted in interest payments.

Nearly all of those surviving compromised with the bondholders and either paid off their indebtedness in cash at a great reduction, or issued new bonds which were exchanged for the old ones, in some cases paying less than 30 per cent of the face value of the indebtedness.

The causes for the failure of the districts were so numerous, and are so well explained in the appendix above named, it is not necessary to enumerate them here. Lest the reader should unthinkingly condemn the irrigation district system, he is earnestly urged to read the history of the rise and progress of the districts as set forth by Mr. Adams.

Most of those districts which reorganized, paid off their indebtedness, and again started with a clean balance sheet, as it were, have been successful in building up prosperous communities.

The Wright act, in its general provisions, was incorporated into the laws of many western states and the results in all were very similar to those in California.

The experience of investors who lost not only the interest for a long term of years, but as stated above, also sacrificed a large part of the principal invested, caused all bonds issued for the development of irrigation enterprises to be regarded with ill favor in the financial marts of the world. It became impossible for irrigation districts in California or elsewhere, no matter how meritorious the project might be, to dispose of their bonds excepting at ruinous rates of discount.

With a view of restricting the haphazard formation of districts and of controlling the administration of those formed so as to make it more difficult to create indebtedness, drastic changes were made in the law by the substitution in 1897 of the Bridgeford act for the Wright law. Further amendments were enacted from time to time, all looking to raising the credit of irrigation districts to a firm basis.

One of the reasons given for the low value of irrigation district bonds was the fact that they were not available for all the purposes accorded to school district, county and city bonds. Because of the uncertainty inherent in many irrigation enterprises as to their ability to develop, and the absence of authority outside of the district itself to determine the feasibility of successful development, it was difficult to enlist legislative sanction to placing irrigation district bonds on a parity with the others mentioned. A law was enacted in 1911, and since amended, providing that irrigation district bonds would be given all of the privileges accorded to other bonds provided they were certified by the State Controller as having been approved by a commission created for the purpose.

In 1913 the district law was amended so as to require the State Engineer to examine and report upon the feasibility of the project before the organization of a proposed district. Also requiring plans and estimates to be submitted for his approval before bonds could be issued.

While these provisions of the law are quite fully abstracted in the addenda to Appendix B, it is considered desirable to epitomize here those provisions wherein the Department of Engineering is brought into close relations with the formation of new districts and the issuance of bonds by all districts for the acquisition of water or of works to supply water to the districts.

Organization.

To organize a district there must be presented to the Board of Supervisors of the county in which the proposed district is situated or in which the greater part lies, a petition praying for the organization of such district. Said petition must be signed by a majority in number of the landowners within the district, representing a majority of the

value of the lands in the district according to the last equalized assessment thereof made by the County Assessor. Said petition must be presented at a regular meeting of the board.

A notice that said petition will be presented must be advertised in some newspaper, having a general circulation in the proposed district, for a period of two weeks before the date of presenting it to the Board of Supervisors. Said notice must recite the intention to present the petition, state the source or sources of water supply and the lands to be embraced in the district, or the boundaries thereof. On or before presenting the petition a copy of the notice must be filed in the office of the State Engineer.

Upon its presentation the board proceeds to consider the matter as to whether the petition contains the names of a majority of the property owners, and whether the petitioner represents a majority of the value of land in the district.

Minor irregularities are not considered, but finding that the petition complies with the requirements of law in the two matters mentioned, the board by resolution so declares; directs a copy of said resolution to be forwarded to the State Engineer; and continues hearing thereon "for one month or from time to time *not exceeding one month in all.*"

The State Engineer is required to make such examination of the project as he deems necessary. He gives particular attention to the following three matters:

1. Whether there is a sufficient supply of water available. The proponents of the district may not have a right to any water, but if it can be had by appropriation under the laws of the state, or if there is a sufficient quantity that may be purchased, or if water in sufficient quantity is being used for other purposes and can be acquired by condemnation under right of eminent domain, it is "available."
2. Whether the lands are susceptible of irrigation. By "susceptible of irrigation" is taken to mean that by irrigation the production and value of crops will be enhanced to an extent commensurate with the cost.
3. Whether the water and the works to deliver it to the land will not cost more than the lands can reasonably pay.

Finding the three conditions favorable, the district is feasible and the State Engineer reports to the Board of Supervisors that he does not find anything that would warrant him in reporting against the formation of the district.

If the State Engineer reports that the district is not feasible and makes no recommendations for changes, then hearing by the board must be continued for one month and then dismissed, unless a petition be then presented signed by three-fourths of the landowners in the district, praying for the formation of the district. In such case, the Board of

Supervisors may complete the formation of the district notwithstanding the adverse report of the State Engineer.

The State Engineer may find that the available supply of water is not sufficient for the purposes of the district as proposed, in which case he may recommend another or additional source, or the modification of the area of the district to correspond with the water supply. He may recommend the exclusion of lands not susceptible of irrigation, or the inclusion of other desirable lands in the district.

His recommendations may be adopted by the board or not, as it pleases, but unless he reports against the formation of the district, it may be formed as the board sees fit. The State Engineer's recommendations are advisory only.

Should the State Engineer fail to report, "it shall not jeopardize the formation of the district," the law says, and in the absence of a report the Board of Supervisors may authorize the formation of the district.

The State Engineer's report having been favorable, or his recommendations approved, the Board of Supervisors fixes a time for election, appoints election officers and advertises the date and purpose of the election to form the district.

At the election, all persons qualified to vote at any general election may participate. In addition to voting upon the question of organizing the district, the electors also vote for the officers of the district, three or five directors, as indicated in the petition, and ordered by the Board of Supervisors, an assessor and tax collector.

The result of the election is canvassed by the Board of Supervisors. A majority vote carries, and upon the qualification of the officers elect they assume charge of the affairs of the district.

The directors of a district are authorized to incur indebtedness in behalf of the district, for engineering services and other business of the district to the extent of 50 cents an acre, or in case of a district of less than 4,000 acres, the limit of indebtedness is $2,000. Against this indebtedness and pending the collection of assessments warrants may be issued against the district treasury, which warrants when registered in the district treasury draw interest at the rate of 7 per cent a year.

Bonds.

A district desiring to issue bonds for the purpose of acquiring water, water rights and irrigation works, submits plans therefor, together with estimates of cost, to the State Engineer. The plans are required to be prepared by a competent hydraulic engineer.

The State Engineer examines the plans, makes such additional surveys and investigations as he deems necessary and within 90 days must report his conclusions to the board of directors of the district.

He may recommend changes in the plans, and submits his estimate of the amount of bonds necessary to carry out the project under the plans as approved or modified by him.

In the light of the recommendations of the State Engineer, the board of directors determines the amount of bonds required, and so declares by resolution entered in the minutes of its meetings.

The report and recommendations of the State Engineer are advisory only, and may be ignored by the directors, who may determine according to their own ideas, how much bonds are required.

After the board has recorded its conclusions as to the amount of bond issue, a petition must be presented praying that an election be called upon the question of issuing bonds. The petition must be signed by the landowners representing a majority of the area of the district.

After due hearing upon the petition an election is ordered and if the vote is favorable by two-thirds voting therefor, the bonds are issued.

Bonds of an irrigation district may bear interest not exceeding 6 per cent a year. They are sold on competitive bids to the highest bidder.

Interest and principal of bonds are paid from taxes levied upon the lands.

No sinking fund is provided for the redemption of bonds, but in lieu of such a fund, the bonds are issued in series, and redeemed at specified times in progressively increasing percentages of the whole; as at 21 years after issuance 2 per cent are redeemed. In the 22d year, 2 per cent more. In the 23d and 24th years, 3 per cent each, and so on to the 39th and 40th years when 8 per cent of the principal each year is paid off and the debt canceled.

Some districts elect to begin paying off the bonds at an earlier date, depending upon the prospects for more or less rapid development of the district. It is considered poor economy to continue paying interest upon the whole issue after all the district has been brought under cultivation and the lands presumably have reached a paying basis.

Validation of bonds.

Prior to 1911, irrigation district bonds were not available for all purposes that other municipal bonds are, that is, they were not available for investments of trust funds, savings and insurance funds, state school funds, and could not be deposited with the State Treasurer as security for many purposes for which county, city or school district bonds are accepted.

In 1911 the legislature passed an act which was amended in 1913, providing that irrigation district bonds should be available for all the purposes named, *provided*, they bear a certificate of the State Controller reciting that they are available for those purposes, and that said bonds are entitled to said privileges by virtue of an examination made by a

commission, composed of the State Engineer, State Superintendent of Banks and State Attorney General.

A district desiring to have its outstanding bonds or a contemplated issue made available for all the purposes named, by its board of directors applies to the commission to have its project examined for which the bonds are or will be issued.

The theory of the composition of the commission is that the State Engineer will pass upon the engineering features of the enterprise; the Attorney General upon the legality of all proceedings and validity of water rights, etc., and the Superintendent of Banks will ascertain the sufficiency of security offered by the district and the general safety of the bonds as an investment.

The Irrigation District Bond Commission upon request from a board of directors, proceeds to make a thorough investigation of the districts and its affairs and reports in writing with particular attention to the following matters:

(*a*) The supply of water available for the project and the right of the district to so much water as may be needed.

(*b*) The nature of the soil as to its fertility and susceptibility to irrigation, the probable amount of water needed for its irrigation, and the probable need of drainage.

(*c*) The feasibility of the district's irrigation system and of the specific project for which the bonds under consideration are desired or have been used, whether such system and project be constructed, projected or partially completed.

(*d*) The reasonable market value of the water, water rights, canals, reservoirs, reservoir sites and irrigation works owned by such district or to be acquired or constructed by it with the proceeds of any of such bonds.

(*e*) The reasonable market value of the lands included within the boundaries of the district.

(*f*) Whether or not the aggregate amount of the bonds under consideration and any other outstanding bonds of said district, including bonds authorized but not sold, exceeds sixty per centum of the aggregate market value of the lands within said district and of the water, water rights, canals, reservoirs, reservoir sites, and irrigation works owned, or to be acquired or constructed with the proceeds of any of said bonds, by said district, as determined in accordance with paragraphs (*d*) and (*e*) in this section.

(*g*) The numbers, date or dates of issue and denominations of the bonds, if any, which the commission shall find are available for the purposes provided for in section 7 of this act, and, if the investigation has covered contemplated bonds, the total amount of bonds which the district can issue without exceeding the limitation expressed in paragraph (*f*) of this section.

The written report of the commission is filed in the office of the State Controller and forms the basis for his certificate that the bonds of the district are available for the purposes enumerated.

During all construction work, to be paid for out of the proceeds of the sale of bonds, the district is required to make periodical reports of progress to the State Engineer.

The State Engineer may at any time make an examination of the affairs of any irrigation district, and make such report thereon as he may deem advisable.

The marked advance in the price offered for irrigation district bonds bearing the certificate of the State Controller is evidence that the safeguards afforded by the administration of the amendments just quoted is having the desired effect in the bond markets. The latest quotations have placed some district bonds above par which a few years ago were difficult to dispose of, even at a substantial discount.

Attention is invited to certain desirable amendations to the provisions of law as above set forth, which are here briefly discussed.

Upon the Board of Supervisors finding that a petition for the formation of a district conforms to the requirements, the State Engineer is notified and continuance ordered for a period not to exceed one month to receive his report as to the feasibility of the project.

If the State Engineer receives the notice of the board's action promptly and is prepared to enter upon the examination without delay a month is none too long a time when conditions are most favorable.

But sometimes several days elapse (in some instances three weeks or more) between the day of fixing the date to reecive the report and the receipt by the State Engineer of the notice of the board's action.

It is not always possible to detach an employee of the department from work under way, and that circumstance may cause delay.

Frequently the proponents of a district have little or no reliable information bearing upon the project, and the investigation partakes of original research, and it is impossible in the time allotted to gather sufficient data, excepting in the simplest of cases, to enable the investigator to reach conclusions that will do justice either to himself or the project.

Furthermore, the authority of the investigations should go to fixing the boundaries of the district. It would seem to be a proper function of the Department of Engineering to make all necessary preliminary investigations for the proper initiation of proceedings to organize a district. Oftentimes proponents of a meritorious project are without data, and to obtain it imposes an unjust burden upon a few.

It is suggested that all engineering investigations for the state should be made by the Department of Engineering at the state's expense. There seems to be no objection, however, to having the district reimburse the state as soon as it becomes in a position to do so.

In the matter of a district issuing bonds, the plans of work proposed to be executed from the proceeds must be submitted to the State Engi-

neer. His recommendations are purely advisory and may be accepted or rejected by the board of directors. This is not believed to be consistent with the mandatory provision that he *must* examine the plans prepared by the district.

Again: The law provides that during the construction of work to be paid for from the proceeds of bonds, copies of monthly reports made to the directors must be sent to the State Engineer. Many districts do not exact progress reports of construction, hence do not have copies to send.

The law declares that the State Engineer "may at any time make or cause to be made an examination of the affairs of any irrigation district or call upon the authorities of such district for such information as he may desire and make such report thereon as he may deem advisable." But it is not stated to whom he shall report nor is authority given to him or anyone else to correct matters which he finds need correction.

This department holds that when the state has given moral support to a district's bonds as it does by the certificate of the bond commission, it should have the power to supervise all work executed with the funds obtained from such bonds, and to enforce adherence to those plans upon which the commission based its approval, or, if the plans must be changed, such alteration should be approved by competent state authority.

New districts.

Since the date of the last report, to November 1, 1916, there have been 16 applications for authority to organize new irrigation districts. Twelve were favorably considered, two were not reported upon for lack of time to make the necessary investigations. One of these was organized under the provision that failure of the State Engineer to report shall not jeopardize or delay the organization of a district. The other failed of organization by adverse vote in the election.

Two proposed districts have been examined and proceedings are pending at the date of this writing, November 1st.

Five of the districts have submitted plans for approval upon which estimates of needed bonds were made. One district named in the former report has also submitted plans.

The following table gives information in detail concerning all districts receiving the attention of the State Engineer since the last biennial report:

TABLE No. 13.

Irrigation Districts Examined for Organization or Bond Issues, 1915-1916.

District	County	Date organized	Area, acres	Bonds authorized
Alpaugh	Tulare	Feb. 23, 1915	7,576	$283,000 00
Anderson-Cottonwood	Shasta	July 14, 1914	32,500	480,000 00
Cardiff	San Diego	Mar. 10, 1916	1,000	
Carmichael	Sacramento	Jan. 5, 1916	3,113	90,000 00
Honey Lake	Lassen	Aug. 29, 1916	31,000	
Jacinto	Glenn	Pending		
Lindsay-Strathmore	Tulare	Oct. 8, 1915	15,775	1,400,000 00
Paradise	Butte	Feb.	10,000	
Princeton-Cordova-Glenn	Glenn	Pending		
Southern Lassen	Lassen	Dec. 21, 1915	31,000	
Stratford	Kings	May, 1916	9,200	
Terra Bella	Tulare	Aug. 7, 1915	12,670	1,000,000 00
Waterford	Stanislaus		14,434	517,000 00
Webster	Madera	May, 1916	15,000	
Westside	San Joaquin	Aug., 1915	11,700	310,000 00

Bonds validated.

In the discussion of the relation of the Department of Engineering to irrigation districts, the operation of the bond validation act was described.

While an unvalidated bond, if issued by a sound district, may be as good an investment so far as concerns interest on the money it represents and the security for its ultimate payment as is a validated bond, nevertheless since the enactment of the validation act unvalidated bonds have little standing in the bond market.

During the two years past the Bond commission has received requests to pass upon the bonds of seven districts, two of which have been investigated and the bonds approved as follows:

TABLE No. 14.

Irrigation Districts Investigated and Bond Issues Approved by the Irrigation District Bond Commission.

Name of district	Area of district, acres	Amount of bonds approved	Value of all property	Per cent of bonds to property values
Imperial	512,000	$3,500,000	$40,000,000	88
Anderson-Cottonwood	32,500	480,000	1,900,000	25

The projects of Alpaugh, Carmichael, Lindsay-Strathmore, Terra Bella and Waterford districts are now being investigated by the Commission.

Waterworks districts.

In 1913 the legislature passed an act providing for the creation of county irrigation districts upon the same general lines as provided for the organization of irrigation districts excepting that the administration of the district is in the county authorities instead of local district officers. The Board of Supervisors of the county acts as a board of directors for the district.

In 1913 the legislature changed the title of these districts to county waterworks districts, and provided that bonds of such districts should be available for the same purposes as irrigation district and other bonds upon their being validated by a commission composed of the personnel of the irrigation district bond commission.

Three districts organized under this act have been investigated and their bonds approved as follows:

TABLE No. 15.

County Waterworks Districts Investigated and Bonds Approved by the County Waterworks Bond Commission.

Name of district	Area, acres	Amount of bonds	Value of property	Ratio of bonds to property values
Los Angeles County—				
Waterworks District No. 1	400	$30,000	$199,400	15
Waterworks District No. 2	143	15,000	60,000	25
Waterworks District No. 3	76,080	2,604,000	27,600,000	24½

All of these districts are in Los Angeles County. No. 1 embraces nearly all of the famous San Fernando Valley, which, since the district was organized, has been annexed to the city of Los Angeles, including nearly the whole district in the city limits.

The creation of this district affords a market for a large part of the surplus waters of the city brought from Owens River by the great Los Angeles aqueduct.

One of the other districts, No. 1, is located south of and adjoining the city while the other, No. 2, is in fact a municipal water supply organization for the village of Norwalk.

Needed legislation.

In order to give the state equal opportunity with private interests in ascertaining and promoting opportunities for economical irrigation development, and to assist communities desiring to form irrigation districts at the time or times assistance is most needed and hardest to pay for by community effort, this department, when deemed in the public interest, should have both the authority and the means to make surveys and investigations *of promising situations* of lands and water

supplies available for community utilization. Data gathered in such surveys and investigations are of permanent value to the public and it is an unnecessary hardship to require communities to pay the cost of these initial engineering studies, and an unwarranted hindrance to progress to delay them until such time as the communities here become sufficiently organized to pay their cost.

Although the amendments to the irrigation district law enacted at recent sessions of the legislature have greatly strengthened the districts working under them, experience points to several desirable changes to which it is desired to call attention.

1. Before a petition for the formation of a district is presented to the Board of Supervisors, the State Engineer should be called in to make investigations.

He should be given funds with which to conduct examination not only into the water supply but also into the nature of the soils as to their adaptability to irrigation and whether the cost will or will not be greater than the lands can bear. He should have authority to decide upon the exclusion or inclusion of lands. He should also be given time commensurate with the magnitude of the project and the difficulties encountered in which to make the investigations and report, and finally his report should not be lightly set aside or ignored.

When the district organization is completed, and funds are available the cost of the investigation might be returned to the state, but in case the report of the State Engineer should be adverse to the project or for other reasons it should fail to complete organization, then the state should stand the loss.

2. Under the present law a district may be formed consisting of many tracts of land not joining or not necessarily contiguous. After a district is organized, however, lands outside the boundaries may be included upon petition, but only if they are contiguous.

If the supply of water is more than sufficient for the needs of the district any lands susceptible of irrigation from the district's water should be annexed on petition, even though not "contiguous."

3. There should be some provision for the consolidation of two or more districts when their interests would be benefited thereby. Instances are known where if two adjoining districts were under one management, the use of the water in times of scarcity could be alternated with benefit to both.

At least one instance is called to mind where it seems doubtful if either of two districts will be able to finance separate projects, while if they were united they could probably find means to construct one system to serve the lands of both.

4. The State Engineer is required to examine the plans and estimates for the construction of works for which it is contemplated to issue

bonds; but his report and recommendations are advisory only and the district may ignore them entirely. Although the law directs that progress of construction shall be reported to the State Engineer periodically, no authority is vested anywhere to compel a compliance with the law. He is authorized to examine work in progress but not empowered to stop that work or change it if he finds it is not being executed according to the plans approved. He is given no funds with which to pay the expense of inspection and examination.

His report on the plans should be binding. He should be able to exercise close supervision of the work and have power to enforce compliance with the plans.

It is not contended here that the permission of organizing a district should rest in the judgment of the State Engineer alone. On the contrary it might be better to submit the questions of area, of boundaries, of inclusion or exclusion of lands, and the general industrial feasibility of the proposed district to a state land commission or irrigation board, leaving the research work—the gathering of physical data—to the Department of Engineering.

Likewise the enforcement of police regulations governing construction according to the plans might be delegated to another body, the department furnishing the engineering knowledge and skill necessary for intelligent supervision and direction.

These matters are commended for the consideration of the coming legislature.

COOPERATIVE RESEARCH.

The state of California since 1903 has been cooperating with different branches of the national government in prosecuting investigations and studies of her natural resources. Appropriations are made at each session of the legislature and in pursuance of the acts, agreements are entered into between the State Engineer in behalf of the state, and representatives of the government for cooperative research, and allotments made of the funds appropriated to cover the state's portion of the expense of making the investigations.

The agreements made during the biennium just closing are as follows:

With the Director of the United States Geological Survey, for:

Topographic surveys.
Water resources investigations.

With the Department of Agriculture, Office of Public Roads and Rural Engineering, for:

Irrigation and drainage investigations.

These agreements are made to run only one year and are renewed annually.

The gathering of the information included in the above subjects is very properly a function of the Department of Engineering, but to provide the department with the requisite equipment for field and laboratory work to maintain the necessary working force, would require a large appropriation. Furthermore, the work accomplished by the department, acting alone, would be duplicate of a great deal that has been done before and that would follow in the regular progress of the work of the other governmental investigators.

By these cooperative arrangements the state obtains the service of already organized corps of experienced investigators possessing all the best apparatus and instruments, and for their service the state is required to pay only a portion of the operating expenses. The appropriations made by the congress for the matters under discussion are too small to permit of any great amount of work being accomplished in any one state, but it is the policy of the government to give preference to those states which desire to cooperate, and the practice is to allot an amount equal to the state's appropriation.

It should be borne in mind that, in addition to the many advantages resulting from cooperative work, all money appropriated by the state is met by a like amount from the federal treasury and nearly every dollar is expended within the state.

TOPOGRAPHIC SURVEYS.

The character of the cooperative topographic surveys made in accordance with the agreement with the Director of the United States Geological Survey is summarized as follows:

The order in which the field work is prosecuted in different parts of the state is fixed by agreement from time to time as the work progresses. The surveys are executed in a manner sufficiently elaborate to prepare maps upon scales which are agreed upon for different localities, and exhibit the hydrography, hypsography, public culture, and all public land and county boundary lines which are marked upon the ground.

The information secured by the surveys is published in atlas sheets of convenient size, called quadrangles. The sheets of paper are 20 x 16.5 inches in dimensions, the territory embraced in each quadrangle covering 15 minutes, 30 minutes, or one degree of latitude, and the same of longitude, according to the scale of the publication. Three scales are employed. The largest scale used in standard sheets is 1:62500, corresponding very nearly to one mile to one inch. Maps drawn on this scale are those of thickly-settled communities or industrially important sections of the country. An intermediate scale of 1:125000, or about two miles to the inch, is employed for the greater part of the country, while the smallest scale, 1:250000, or about four miles to the inch, is used for territory of relatively slight industrial

importance or sparse population, such as the desert regions. A few special maps of important mining districts or other limited areas are issued on special scales suited to the requirements of the country mapped, when sheets are designated by name, usually that of some important physical feature, thus: Yuba City quadrangle, Pyramid Peak quadrangle, etc. That portion of the Sacramento Valley lying west of the Sacramento River has been published in sheets 28 x 40 inches and covering several quadrangles, the scale being 1:31680, or one-half mile to the inch. These are found very convenient in studying irrigation and reclamation in these regions where projects embrace large areas.

The maps are sufficiently detailed to serve as base maps on which are represented the character of the soils and forests of the area surveyed, and show all principal objects, natural or artificial, such as streams, lakes, shore lines, reservoirs, canals, important wells, springs, railroads, highways, power-transmission lines, principal houses, villages, towns, and cities, quarries, mills and other industrial plants, all with great clearness and fidelity to position.

The hypsography is shown by contour lines with vertical intervals of five to 100 feet, according to the smoothness or ruggedness of the terrene. The heights of important points are determined and enduring monuments and bench marks are established, the elevation and location of which are found by precise methods. Along both sides of the Sacramento River, from Suisun Bay to a point several miles above the city of Sacramento, there have been set solid concrete monuments, in which are imbedded aluminum tablets upon which are marked the elevations to the nearest foot. At frequent intervals all over the territory surveyed are placed other bench marks which consist of iron pipes set solidly in the ground and capped with a bronze or aluminum cap, marked in the same manner as the tablets on the concrete monuments. A record of the location, and the elevation in feet and fractions, of all bench marks is kept on file in the office of this department. All elevations noted by the survey are determined by precise level lines run and checked with the utmost care, and are referred to mean sea level as deduced from long series of observations.

The United States Geological Survey conducted topographic surveys in 30 states and one territory during the fiscal year ending June 30, 1914, and mapped 19,230 square miles of territory. The total area of the country now mapped amounts to 40.9 per cent of the entire area of the continental United States and 22 per cent of Hawaii.

In California there were 5,793 square miles surveyed during the biennial period ending June 30, 1916. The total area now mapped amounts to about 74 per cent of the entire surface of the state. The

surveys were made by the United States Geological Survey, acting alone or in cooperation with the state of California.

The Survey, independently of cooperative assistance, completed the survey and mapped the following: Seiad, Sawyer's Bar, Preston, Cholame and White Mountain, 30-minute quadrangles; San Juan Bautista, Morgan Hill, Point Reyes and New Almaden, 15-minute quadrangles. The resurvey of Mare Island and revision of portions of San Francisco, Concord, Hayward and Alameda quadrangles were completed.

In cooperation with the University of California, the survey of Santa Rosa quadrangle was completed and the map has been published. In cooperation with the city of Los Angeles, the Elizabeth Lake quadrangle and part of the Kramer quadrangle were surveyed and mapped. The result of those surveys was embodied by the city in a very complete relief map of the Los Angeles aqueduct.

Those quadrangles surveyed in cooperation with the Department of Engineering are enumerated in the report at the end of this article.

All of the quadrangle maps of the Sacramento Valley are now published.

Special effort has been put upon the survey of the San Joaquin Valley in response to the need for the data in studies of irrigation, reclamation and flood control problems.

In the San Joaquin Valley the topographic survey at the close of June, 1914, had covered about 1,180 square miles. For the period ending June 30, 1916, the survey was extended over nearly 1,600 square miles, making the total area of the valley now surveyed and mapped about 2,680 square miles.

In addition to the 1,600 square miles mapped, 109 triangulation stations were occupied, 92 stations marked and 183 miles of primary levels run with 47 permanent bench marks established.

In two instances the topographic surveys were extended ahead of the regular progress in order to cover special areas for study of irrigation and flood control urgently needed.

The cooperative topographic surveys have been conducted under the supervision of Mr. George R. Davis, geographer in charge of the Pacific division, directed by Mr. R. B. Marshall, chief geographer, and W. H. Herron, acting chief geographer.

Their report in detail for the two years ending June 30, 1914, follows:

Report of topographic surveys in cooperation between the United States Geological Survey and the state of California, for the fiscal years beginning July 1, 1914, and ending June 30, 1916.

In accordance with the cooperative agreements signed August 8, 1914, and June 24, 1915, by George Otis Smith, Director, for the United States Geological Survey, and August 26, 1914, and June 29, 1915, by W. F. McClure, State Engineer, for the state of California, the Federal Survey allotted $14,000 each year, and the state an equal amount, for cooperative topographic surveys in the state of California for the fiscal years ending June 30, 1915, and June 30, 1916.

The following is a summary of the field and office work accomplished during the above period under the general direction of R. B. Marshall, chief geographer, W. H. Herron, acting chief geographer, and under the immediate supervision of George R. Davis, geographer in charge of the Pacific division:

FIELD WORK.

Quadrangles	Counties	Publication scale	Area mapped, sq. miles	Primary Levels		Secondary traverse, miles	Triangulation	
				Miles	Perm. marks		Station occupied	Station marked
Denair	Stanislaus	1:31,680	47					
Cressey	Stanislaus Merced.	1:31,680	59					
Ceres	Stanislaus	1:31,680	59					
Crows Landing	Stanislaus Merced.	1:31,680	59				1	
Mitchell School	Stanislaus Merced.	1:31,680	59				1	
Winton	Merced	1:31,680	59					
Minturn	Madera Merced.	1:31,680					1	
Merced	Merced	1:31,680	60				2	
Hopeton	Merced	1:31,680	59					
Turlock	Merced	1:31,680	59				1	1
Copperopolis	Calaveras Stanislaus. Tuolumne.	1:62,500	158	7	1			
Stevinson	Merced	1:31,680	60				3	2
No. 7	Mariposa Merced.	1:31,680	59	11	3		1	
Arena	Merced	1:31,680	59				5	5
No. 9	Mariposa Merced. Madera.	1:31,680	59	10	3			2
LeGrand	Madera Mariposa. Merced.	1:31,680	59	6	3			2
Gustine	Merced Stanislaus.	1:31,680	60				4	
Planada	Merced	1:31,680	60	10	1		1	
Plainsburg	Madera Merced.	1:31,680	34	6	1		1	
Atwater	Merced	1:31,680	60					
Newman	Merced Stanislaus.	1:31,680	60				1	
Ingomar	Merced	1:31,680	59				1	1
No. 74	Mariposa Merced.	1:31,680	37	8	3			
Las Garzas Creek	Merced Stanislaus.	1:31,680	55	14	4		1	
Indian Gulch	Mariposa Merced.	1:62,500	90	11	3		5	3
Snelling	Merced Stanislaus.	1:31,680	59	7	2			
Merced Falls	Mariposa Merced.	1:31,680	14	4	1			
La Grange	Merced Stanislaus. Tuolumne.	1:31,680	16	2	1			

FIELD WORK—Continued.

Quadrangles	Counties	Publication scale	Area mapped, sq. miles	Primary Levels		Secondary Levels, miles	Triangulation	
				Miles	Perm. marks		Station occupied	Station marked
Orestimba Creek	Stanislaus	1:31680	19					
No. 10	Merced			2	1		4	4
	Madera.							
Deadman Creek	Merced			8	2		1	1
Kearney Peak	Fresno						3	2
Jesbel	Madera						1	1
	Mariposa.							
Clovis	Fresno						1	
	Madera.							
Chowchilla Slough	Merced						3	5
Berendo	Madera			4	1		1	3
Fresno	Fresno						3	1
Friant	Fresno						1	
	Madera.							
Herndon	Fresno						1	
	Madera.							
Sharon	Madera			10	2		1	1
Madera	Madera			8	1		3	
Bridge	Fresno						2	2
	Madera.							
No. 15	Madera						3	4
No. 16	Madera						5	
No. 17	Madera						2	
No. 19	Madera						1	3
	San Joaquin.							
No. 20	Fresno						4	3
	Madera.							
No. 21	Fresno						1	1
	Madera.							
San Luis Creek	Merced			11	3		1	
Mariposa Slough	Merced			3			2	
Salt Slough	Merced						2	2
Volta	Merced			14	3		1	1
Los Banos	Merced			3			2	
Center School	Merced						2	
Daulton	Madera			14	4		1	
Trigo	San Joaquin			2				
	Stanislaus.							
Bachelor Valley	Calaveras			13	4			
	Stanislaus.							
Elgin	Merced						4	4
No. 14	Fresno						1	1
	Madera.							
No. 18	Fresno						1	2
No. 22	Fresno							1
No. 23	Fresno						2	2
No. 24	Madera						1	
No. 25	Madera						1	2
Kerman	Fresno						2	2
Kings River	Fresno							2
Dos Palos	Madera						4	3
	Merced.							
Oxalis	Madera						2	3
	Merced.							
	Fresno.							
Firebaugh	Fresno						1	2
	Madera.							
Mendota	Fresno						1	4
	Madera.							
Sheep Ranch	Fresno						2	
Reedley Special	Fresno							1
San Joaquin	Madera						1	1
Sanger	Fresno							2
Wahtoke	Fresno							1
Sultana	Fresno							1
	Tulare.							
Jamison	Fresno						3	5
Tranquillity	Fresno						2	3
Totals			1,597	183	47		109	93

The following members of the topographic branch were engaged in the field work:

Topographic Mapping:

A. O. Burkland, topographer
H. W. Peabody, assistant topographer
A. J. Ogle, assistant topographer
J. B. Leavitt, assistant topographer
S. H. Birdseye, assistant topographer
F. A. Danforth, assistant topographer
C. A. Stonesifer, junior topographer
E. P. Davis, topographer
R. T. Evans, topographer
J. H. LeFeaver, assistant topographer
N. E. Ballmer, assistant topographer
Roscoe Reeves, assistant topographer
R. M. Wilson, junior topographer

Triangulation:

C. L. Nelson, topographic engineer
C. F. Urquhart, topographic engineer
L. F. Biggs, topographer

Primary Levels:

Roscoe Reeves, assistant topographer
D. S. Birkett, assistant topographer

Office Work. The office drafting of the Ceres, Copperopolis, Cressey, Crows Landing, Denair, Riverbank, Klamath River, Merced, Mitchell School, Hopeton, Scott River, Stanislaus River, Turlock, Waterford, Winton, Arena, Atwater, Gustine, Newman, Orestimba Creek, Owens Creek, Planada, Snelling and Stevinson topographic maps was completed and the maps transmitted for engraving. The drafting of the Le Grand and Lagrange topographic maps was each five per cent completed.

Primary level circuits were adjusted for the Copperopolis quadrangle and for the San Joaquin Valley and the results typewritten for publication.

Geographic positions were computed for the Mitchell School, Turlock, Cressey, Winton, Hopeton, Stevinson, No. 8, Atwater, Merced, Planada, Mariposa Slough, Owens Creek, No. 11, Indian Gulch, Plainsburg, Le Grand, No. 9, Deadman Creek, Chowchilla Slough, Salt Slough, Ingomar, Las Garzas Creek, Berenda, Minturn, and No. 10 quadrangles.

WATER RESOURCES.

Investigation, measurement and cataloging of the water resources of the state have been diligently prosecuted for many years by private interests seeking to take advantage of the loose laws to appropriate the waters to private exploitation.

It was not until recent years that the public awoke to the fact that the vast resources of the state, residing in the potential waters of its rivers, brooks and waterfalls; its lakes and glaciers, were fast passing to private ownership, and interposed a staying hand by enacting the conservation laws of 1911.

The government had been engaged in a small way in gathering data as to stream flow, but not until cooperation was established with the state did this character of research assume a degree of activity at all in keeping with its importance to the public.

When the Department of Engineering was created and entrusted with the task of representing the state in these matters, the work of

gathering information began to expand, and by 1909 there were 70 gaging stations established on the streams of the state. That was not many when the extent of territory and mileage of stream is considered, but by cooperating and uniting the funds of state and nation the work was prosecuted and data began to accumulate.

Since 1911 there have been about 300 gaging stations established. Some of these were maintained but a short time, while others have been constantly maintained and the records obtained show the quantity of water flowing every day of the year.

Records of stream flow are highly important, in fact absolutely necessary, in devising projects for irrigation, reclamation, flood control, power development, and navigation, or in fact any use to which flowing water may be devoted. The lack of complete records is keenly felt by the Department of Engineering and all others in attempting to solve the many problems of hydroeconomics so vital to the prosperity of the state.

At the close of June last there were 160 gaging stations in operation distributed as far as practicable so as to give the greatest value to the entire state. Wherever great interests are involved extra effort is put forth to obtain data. Several new stations have been established in the Tuolumne drainage basin in cooperation with the city of San Francisco in studies of the Hetch Hetchy project.

The city of Los Angeles has cooperated and enabled more extensive measurements to be made of the stream flow in Owens River basin.

Intensive study has been given to the hydrography of San Diego County, the results of which will soon be published. The unprecedented floods in that region early in 1916 played havoc with the gaging stations, many of which were completely washed away and the conditions so changed that they had to be abandoned or new locations found. The loss in equipment alone amounted to about $2,600.

More extensive studies have been made of the run-off and flood conditions affecting the regions about Los Angeles, due to cooperation of the Forest Service and the county officials.

Much additional data has been obtained concerning Merced River through the assistance of the Bureau of Parks of the Interior Department.

The work of stream measurement has also been much assisted by funds furnished by the State Water Commission.

The accuracy of the data obtained has been greatly improved. The number of stations equipped with automatic registering apparatus is being constantly augmented, as funds will permit. All important stations should be so equipped and the instruments housed in permanent structures.

METHODS OF STREAM MEASUREMENT.

To ascertain the quantity of water flowing at a given point the cross section of the stream is carefully measured, the measurements referred or "tied" to some permanent monument or mark established nearby, where it is safe from disturbance.

A graduated rod or staff is set up marked in feet and subdivisions, and with the zero generally at the surface of the water, or if it can be ascertained, at the height of the lowest low water known.

At important stations, particularly if the stream is subject to frequent fluctuations, and in locations where observers can not frequently visit the station, automatic gages are installed, which indicate every variation in the height of water and make a continuous record of it on paper. The mechanism of the automatic gages is operated by clockwork and the records are usually arranged to cover a week, at the end of which time a new sheet must be put in and the clock rewound. These gages are delicate instruments and must be well protected from the weather as well as from vandalism of chance passers-by.

Measurements of the velocity of the flowing water are taken at intervals, effort being made to obtain such measurements at different stages of the water as will obtain data for calculating the rate of flow at all stages. This is called rating the station and a table of the flow for each fraction of a foot in height, shown on the gage, is prepared from these measurements and calculations, which computation is called a "rating table."

Several methods are used to measure the quantity of water flowing in the streams, as by obtaining the depth flowing over a dam or weir, or by measuring the velocity of the current with a current meter, or in some instances by chemical analysis.

The weir method is preferred where conditions make it reliable. The chemical method is considered very efficient, but has not become well known.

The current meter method is the one generally used, and by permission of the Director of the United States Geological Survey illustrations of the instruments used and their method of employment are herewith presented.

The several methods employed are fully described in the publications of the Survey, particularly in "Weir experiments, coefficients and formulas," designated as Water Supply Paper 200; "Turbine water wheel tests and power tables," as Water Supply Paper 180; and "Surface water supply of the United States 1907–8, Part IX." Water Supply Paper 251. These volumes may be purchased at a nominal price from the Superintendent of Documents, Washington, D. C.

The results of stream measurements are expressed in second-feet or acre-feet. A second-foot is the prism of water one foot deep, one foot

wide and moving a foot of distance in a second of time. A stream flowing a second-foot, or as it is sometimes written, a cubic foot per second, would fill a box a foot square and a foot deep every second, and amounts to 448.8 gallons a minute. In ordinary practice it is regarded as 450 gallons a minute.

An acre-foot of water is the quantity that would cover an acre of space one foot in depth, and amounts to 43,560 cubic feet.

One second-foot of water, running continuously for twenty-four hours, will cover an acre to a depth of 1.98 feet or amount to 1.98 acre-feet. For many computations it is sufficiently accurate to assume a second-foot to be equivalent to two acre-feet a day.

In California and some other states another unit of measurement is used, called the miner's inch. This is, theoretically, the quantity of water that will flow through an orifice one inch square, placed at a certain distance below the surface. The depth below the surface, called the "head," varies in different states and in different localities in the same state.

The statutes of California require an appropriator to describe the extent of his appropriation, stating the quantity he claims "in inches, measured under a four inch pressure." Hydraulicians are agreed that pressure means "head" which is the vertical distance from the surface of still water to the center of gravity of the orifice. Under such conditions a miner's inch would be equivalent to 0.02 (one-fiftieth) second-foot or, in round numbers, nine gallons a minute.

By a statute enacted in 1903, however, it is declared that a miner's inch shall be equivalent to one-fortieth second-foot, or 11.25 gallons a minute, and the statute of 1913, defining the powers of the State Water Commission, directs that an inch of water shall be equivalent to one-fortieth of a second-foot.

These contradictory provisions should be repealed, and one enacted requiring all quantities to be described with definite figures; gallons per minute for domestic use or pumping, second-feet for rate of flow and acre-feet for quantity.

The results of the observations at the gaging stations established at various points on the streams of the state are published from time to time in the bulletins issued by the Geological Survey under the title of Water Supply Papers.

These published records give the following information:

Description of station, and of its characteristics.
List of discharge measurements made on the stream above.
Table of daily gage heights at the station.
Table of daily discharges.
Table of monthly and yearly discharges and run-off.

The records obtained are of inestimable value in the study of the many problems concerning irrigation, reclamation, flood control and navigation, and have been accepted and used very extensively by engineers engaged in operations under either and all of the subjects named.

The records obtained of the flow of Sacramento River and its tributaries were also used by the United States Debris Commission and the Board of Engineers for Rivers and Harbors as a basis for the plan reported to congress for the "Control of Floods in the Systems of the Sacramento Valley and the adjacent San Joaquin Valley," a project involving the expenditure of millions of dollars.

A similar project for the same purpose was proposed several years ago, before the cooperative observations above mentioned had procured complete data. The project was based upon the best information obtainable at that time of the flood flow of the streams, but in the light of later research and from the continuous records obtained, it is known that works for flood control must care for about 130 per cent more water than was formerly believed to be necessary.

A reliable record, then, of the quantity of water poured into the valley by all its streams at flood is necessary to an intelligent study of problems relating to flood control. A knowledge of the amount of low water flow is requisite in discussing means of aiding navigation.

Correct information as to the daily, monthly and annual flow of each stream, and of all combined, is necessary in exploiting irrigation enterprises for the 10,000,000 acres of irrigable land in the Great Valley, and other millions of acres elsewhere in the state.

In furtherance of this last-named object, knowledge is required, too, of the extent to which surplus water can be conserved, and the flow regulated by storage reservoirs.

One of the great assets of the state is nature's storage reservoirs in the vast snow fields at the head of the streams, and yet not one iota of information is collected concerning their condition.

A record of the depth and quantity of water contained in every artificial reservoir for each day is obtainable, but never an effort to ascertain the quantity stored in the snow banks.

It is known from the stream flow records at the end of the season how much water has come down, but if reliable records were systematically made every season of the snow lying in the drainage basins, after a few years rating tables would be devised by which observations in the snow fields would indicate in advance the discharge to be expected for the coming season.

It is not enough that merely the depth of the snow be reported, as that conveys little information, but what it is desired to know is the water content of the snow. After a given basin has been well surveyed, a few

typical locations may be selected for observation representing average conditions, the results from which will enable a close estimate to be made of the quantity of water that will arrive at the gaging stations below.

Such information would be valuable to all having to do with any of the uses of water, but it is particularly desirable in operating reservoirs which might be created for the combined purposes of flood control and irrigation. With a knowledge of the amount of water in storage in the snows, the probable flood flows may be forecast and the proper time be determined when the irrigation water may begin to be stored.

The importance of this subject is so apparent to those of the department who are engaged in studying hydroeconomics that it is urged upon the legislature to give it substantial recognition by an appropriation which will enable this line of research to be entered upon at once and vigorously prosecuted.

The investigations into the water resources of the state by the United States Geological Survey in cooperation with the state of California during the last biennial period have been conducted under the charge of Mr. N. C. Grover, chief hydraulic engineer, chief of the water resources branch, United States Geological Survey, by Mr. H. D. McGlashan, district engineer, whose report will be found at the close of this article.

REPORT TO THE DEPARTMENT OF ENGINEERING ON THE PROGRESS OF THE SURFACE WATER INVESTIGATIONS IN CALIFORNIA BY THE WATER RESOURCES BRANCH OF THE UNITED STATES GEOLOGICAL SURVEY FOR 1914-1916.

By N. C. Grover, Chief Hydraulic Engineer, and H. D. McGlashan, District Engineer.

The investigations in this state during the past two years have been, in general, a continuation of the work outlined in your Fourth Biennial Report. The regular stream-gaging fund provided by the federal government and the state of California, through your department, has been augmented by the appropriations of the State Water Commission. As the money available has been sufficient to maintain only the work under way at the time of the last report, no particular extension has been practicable. It has been necessary to abandon a few of the less important gaging stations, either on account of unfavorable natural conditions or a withdrawal of cooperation, and a small number of new stations have been established. As far as practicable, the work has been so apportioned that it will result in the greatest possible value to the entire state. There are still many points in all portions of the state where additional stream-flow records are greatly needed. The demand for such records can not be met unless the appropriations for the work are increased.

The table which follows shows the gaging stations maintained during the two-year period ending November, 1916. These stations are distributed among major drainage basins as follows: North Pacific, 8 per cent; South Pacific, 27 per cent; Sacramento, 18 per cent; San Joaquin, 34 per cent; Great Basin, 13 per cent.

Stream.	Post Office.
Agua Caliente Creek†	Warner Springs
American River	Fairoaks
American River (Middle Fork)	East Auburn
American River (South Fork)	Placerville
American River (North Fork)	Colfax
Arroyo Seco	Soledad

Stream.	Post Office.
Arroyo Seco	Pasadena
Baxter Creek†	Janesville
Bear Creek	Springville
Bear River	Van Trent
Bear River	Colfax
Bear River Canal	Colfax
Big Creek	Shaver
Big Creek†	Tollhouse
Black Canyon Creek†	Mesa Grande
Boulder Creek (mouth)†	Lakeside
Boulder Creek (Cuyamaca reservoir)	Lakeside
Buckeye	Bridgeport
Butte Creek	Butte Valley
Cache Creek†	Lower Lake
Cache Creek	Yolo
Calaveras River	Jenny Lind
Canada Verde River†	Warner Springs
Carrizo Creek†	Warner Springs
Carson River (West Fork)	Woodfords
Carson River (East Fork)	Markleeville
Cherry Creek	Sequoia
Clavey River†	Tuolumne
Clear Lake	Lakeport
Clear Creek†	Shasta
Coffee Creek†	Coffee
Cosumnes River	Michigan Bar
Cosumnes River (North Fork)	El Dorado
Cottonwood Creek	Dulzura
Crane Valley reservoir	North Fork
Deer Creek	Hot Springs
Deer Creek†	Vina
Dinkey Creek†	Ockenden
Donner Creek†	Truckee
East Walker River	Bridgeport
Eel River	Scotia
Eleanor Creek	Sequoia
Elsinore Lake	Elsinore
Erskine Creek†	Bodfish
Escondido Mutual Water Co.'s canal	Nellie
Falls Creek	Sequoia
Feather Creek	Oroville
Feather River (Middle Fork)	Oroville
Feather River (Middle Fork)	Cromberg
Feather River (North Fork)†	Prattville
Feather River (North Fork) at Big Bar, near	Oroville
Feather River (South Fork)	Enterprise
Fish Creek	Duarte
Fresno River	Knowles
Fresno Flume & Lumber Co.'s flume	Shaver
Gobernador Creek	Carpinteria
Golden Rock ditch	Sequoia
Gold Run Creek†	Susanville
Goodyear Creek	Goodyear Bar
Hat Creek	Hat Creek
Illilouette Creek†	Yosemite
Indian Creek	Crescent Mills
Indian Creek	Happy Camp
Janesville Creek†	Janesville
Jawbone Creek†	Tuolumne
Kaweah River	Three Rivers
Kaweah River (North Fork) at	Kaweah
Kaweah River (South Fork)	Three Rivers
Kaweah River (East Fork)†	Hammond
Kaweah River (Marble Fork)†	Ranger
Kaweah River (Middle Fork)†	Hammond
Kaweah River (North Fork)† near	Kaweah
Kern River	Bakersfield
Kern River	Kernville
Kern River power canal	Isabella
Kings River	Sanger
Kings River (North Fork)†	Ockenden
Klamath River	Requa
Klamath River	Seiad Valley
Kosk Creek	Henderson
Lake Tahoe	Tahoe

Stream.	Post Office.
Lassen Creek†	Johnstonville
Leevining Creek†	Mono Lake
Little Anita Creek	Sierra Madre
Little Stony Creek	Lodoga
Little Truckee River†	Boca
Lytle Creek	San Bernardino
Markleeville Creek, above	Markleeville
Markleeville Creek, at	Markleeville
Matagual Creek†	Warner Springs
McCloud River	Baird
Merced River	Exchequer
Merced River	Yosemite
Merced River at power house	Yosemite
Merced River above Illilouette Creek†	Yosemite
Merced River (South Fork)	Wawona
Middle Eel River	Covelo
Mill Creek	Forest Home
Modesto Canal	Lagrange
Mokelumne River	Clements
Mokelumne River (Licking Fork)	Railroad Flat
Mokelumne River (Middle Fork)	West Point
Mokelumne River (South Fork)	Railroad Flat
Mono Lake	Mono Lake
Monrovia pipe line	Monrovia
Oakdale canal	Knights Ferry
Oregon Creek	North San Juan
Owens Lake	Lone Pine
Owens River	Lone Pine
Owens River	Round Valley
Owens River	Tinemaha
Pacific Light & Power Co.'s canal	Azusa
Pacific Light & Power Co.'s canal	Mentone
Palermo Land & Water Co.'s canal	Enterprise
Pine Creek	Round Valley
Pit River	Henderson
Pit River	Ydalpom
Pitman Creek	Shaver
Putah Creek	Winters
Reeve Davis Con. Mining Co.'s flume	Happy Camp
Relief Creek	Avery
Robinson Creek	Bridgeport
Rock Creek	Goodyear Bar
Rock Creek	Round Valley
Rush Creek†	Mono Lake
Sacramento River	Castella
Sacramento River	Red Bluff
Salmon River†	Somesbar
Salton Sea	Salton
San Antonio Creek	Upland
San Diego River†	Lakeside
San Diego Flume	Lakeside
San Diego River	San Diego
San Diego River	Santee
San Diego River (at diverting dam)	Lakeside
San Diego Flume (at diverting dam)	Lakeside
San Diego River (South Fork)†	Alpine
San Diego River (South Fork) flume†	Alpine
San Dieguito River†	Bernardo
San Dieguito River (at Carroll dam site)	Bernardo
San Dieguito River†	Del Mar
San Gabriel River	Azusa
San Gabriel River (headworks)†	Azusa
San Jacinto River	Elsinore
San Joaquin River	Friant
San Joaquin River	Newman
San Joaquin River	North Fork
San Luis Rey River†	Bonsall
San Luis Rey River	Mesa Grande
San Luis Rey River	Nellie
San Luis Rey River†	Oceanside
San Luis Rey River	Pala
San Luis Rey River†	Warner Springs
San Luis Rey River (West Fork)†	Warner Springs
San Vicente Creek†	Foster
Santa Ana River	Mentone

Stream.	Post Office.
Santa Maria River	Ramona
Santa Ynez River	Lompoc
Santa Ynez River	Santa Barbara
Santa Ynez River†	Solvang
Santa Ysabel Creek	Ramona
Santa Ysabel Creek	Mesa Grande
Santa Ysabel Creek†	Santa Ysabel
Schloss Creek†	Lassen
Scott River	Callahan
Scott River (East Fork)	Callahan
Shasta River	Montague
Smith River (Middle Fork)	Crescent City
Smith River (North Fork)	Crescent City
South Fork Creek	North Fork
South San Joaquin canal	Knights Ferry
Spanish Creek	Keddie
Stanislaus River†	Knights Ferry
Stanislaus River (above Goodwin dam)	Knights Ferry
Stanislaus River (Middle Fork)	Avery
Stanislaus River (North Fork)	Avery
Stanislaus River (South Fork)	Confidence
Stevensen Creek	Shaver
Susanna Creek†	Warner Springs
Swager Creek	Bridgeport
Sweetwater River	Dehesa
Sweetwater River	Descanso
Swift Creek†	Trinity Center
Temescal Creek†	Almond
Temescal Creek	Elsinore
Tenaya Creek	Yosemite
Trinity River	Hoopa
Trinity River	Lewiston
Trinity River†	Trinity Center
Trinity River (East Fork)†	Trinity Center
Truckee River	Iceland
Truckee River	Tahoe
Tulare Lake	Stratford
Tule River	Porterville
Tule River (South Fork)	Porterville
Tule River (North Fork of Middle Fork)†	Springville
Tule River (South Fork of Middle Fork)†	Springville
Tuolumne River	Lagrange
Tuolumne River (above Lagrange Dam)	Lagrange
Tuolumne River (at Hetch Hetchy dam site)†	Sequoia
Tuolumne River (below Hetch Hetchy dam site)	Sequoia
Tuolumne River (at Hetch Hetchy cabin)	Sequoia
Tuolumne River	Groveland
Tuolumne River (South Fork)	Groveland
Tuolumne River (South Fork)	Sequoia
Turlock canal	Lagrange
Utica Gold Mining Co.'s canal	Avery
Ventura River†	Nordhoff
West Pasqual ditch†	Escondido
West Walker River	Coleville
Whiskey Creek	North Fork
Yosemite Creek	Yosemite
Yosemite Power Co.'s canal	Lagrange
Yuba River	Smartville
Yuba River (Middle Fork)	North San Juan
Yuba River (North Fork)	Goodyear Bar
Yuba River (North Fork of North Fork)	Downieville

Much progress has been made in increasing the accuracy of the stream-flow data by the use of improved field and office methods. This has been accomplished without materially decreasing the extent of the investigations. Several gaging stations have been relocated at sites where natural conditions are more favorable and improved equipment has been installed, where practicable.

The Hetch Hetchy work, which was undertaken at the request of M. M. O'Shaughnessy, city engineer, for the city of San Francisco, about two and one-half years ago, has been continued. All gaging stations are equipped with water-stage recorders and the construction has been permanent in character. This work is now

†Station discontinued.

on a very satisfactory basis. On account of the additional cooperation recently furnished by the Bureau of National Parks, the important work in Yosemite Valley has been extended. Two new gaging stations equipped with water-stage recorders have just been completed. The cooperative agreement between the U. S. Forest Service and the county of Los Angeles has resulted in the undertaking of an intensive study of the run-off of streams having their sources in the Angeles National Forest in Los Angeles County. Increased assistance and much valuable stream-flow data are furnished by municipalities, irrigation districts, corporations, and private parties throughout the state.

The floods of January, 1916, in southern California, greatly exceeded the maximum records previously recorded by the Geological Survey. Nearly all the gaging stations in this portion of the state were destroyed, the damage to equipment being approximately $2,600. In a few instances it has been necessary to abandon previous sites and install entirely new stations on account of the great changes in the channels caused by the floods. It is expected that all this work will be reestablished on a satisfactory basis before the rainy season arrives.

The following Surface Water-Supply papers have been published since your last report: Papers 330 and 331, which contain the stream-flow data for stations in California for the year ending September 30, 1912; Paper 340, parts X and XI, which lists all gaging stations maintained in California from 1885 to 1913. There are also lists of publications relating to the water resources of the state, as well as hydrologic reports of general interest. Paper 360 contains stream-flow records for California stations in the Great Basin drainage for the year ending September 30, 1913.

Papers 361 and 391, annual progress reports for California for the years ending September 30, 1913 and 1914, and Paper 390, which contains data for California stations located in the Great Basin drainage for the year ending September 30, 1914, are at the printing office and will be available for distribution in a short time.

The compilation of the stream-flow data for Paper 411 for the year ending September 30, 1915, is nearly completed.

In addition to the regular publications, two special Water-Supply papers are in preparation: "Water Resources of San Diego County," and "Southern California Floods of January, 1916." The former paper will be a complete report covering the geology, ground waters and surface waters to date for that portion of the country west of the divide. The latter paper will include all available data bearing on the recent floods.

In the administration of the work of this branch of the Geological Survey, the district office is maintained at 328, Custom House, San Francisco. A suboffice is retained at 619, Federal Building, Los Angeles, for the convenience of that portion of the state. Data collected by all branches of the Geological Survey may be consulted at either office.

STREAM FLOW.

The result of stream measurements made in the Great Valley is summarized in the following tables. Many intermittent streams pour water into the valley in the rainy seasons, but they are so "flashy" in character that it is impracticable to maintain gaging stations upon them with the funds available for that purpose.

In San Joaquin Valley no perennial streams reach the river from the west side. On the east side are several of the intermittent class of streams, such as Chowchilla and Fresno rivers, Deer Creek, White River, Poso and Caliente creeks, all of which contribute considerable quantities of water in flood times, but are not metered.

In Kern basin the only stream of sufficient size to warrant the maintenance of gaging stations is Kern River.

TABLE No. 16.

Flow of Water Into Sacramento Valley, October 1, 1903, to September 30, 1915.

Stream	Drainage area, square miles	Maximum flood flow second-feet	Maximum mean daily flow, second-feet	Maximum monthly flow, acre-feet	Minimum monthly flow, acre-feet	Maximum annual flow, acre-feet	Minimum annual flow, acre-feet	Mean annual flow, acre-feet	Available storage capacity, acre-feet
Sacramento	10,400	278,000	254,000	4,480,000	265,000	15,900,000	6,370,000	10,858,200	[5]1,316,000
Stony Creek[7]	601	36,000	29,300	391,000	50	894,000	127,000	554,300	144,000
Feather River	3,640	187,000	187,000	2,450,000	59,600	9,340,000	2,090,000	5,883,300	775,600
Yuba	1,220	[6]125,000	111,000	1,410,000	13,800	4,560,000	1,130,000	2,852,700	188,000
Bear[1]	263	25,800	25,800	296,000	806	726,000	87,600	402,500	
American[1]	1,910	119,000	105,000	1,520,000	7,320	6,480,000	1,260,000	3,641,000	
Cache Creek	1,230	20,800	20,100	469,000	0	1,280,000	36,900	654,800	176,500
Putah Creek[2]	805	39,400	39,400	474,000	0	895,300	56,300	500,600	318,000
Totals				11,490,000	346,576			25,347,400	2,868,100
Unmetered streams[3]	3,907	76,000							
Valley[4]	4,250	25,500							

[1]Record beginning 1903-1904.
[2]Record beginning 1905-1906.
[3]Estimated from 50 per cent run-off of rainfall recorded in area for storm of March, 1907.
[4]Estimated from 40 per cent run-off of rainfall recorded for storm of March, 1907.
[5]The capacity of the Big Valley reservoir on Pit River is stated to be 3,196,000 acre-feet, but as the mean annual flow of Pit River at that point for a period of five years was 713,000 acre-feet, that amount is taken as the available storage capacity of the stream at that site. The capacity of Warm Springs Valley and Round Valley and others above Big Valley are omitted, as their storage would simply reduce the flow reaching Big Valley reservoir. To the Big Valley storage is added the storage of a proposed reservoir at Iron Canyon, which is estimated at 603,000 acre-feet.
[6]These figures are the estimate made by the California Debris Commission as the quantity flowing just prior to the destruction of the debris barrier below Smartsville. The maximum recorded at the gaging station was 111,000 second feet.
[7]Station discontinued October, 1912.

TABLE No. 17.

Annual Flow of Sacramento River and Tributaries.

(Expressed in acre-feet for each year, 1903-1904 to 1914-1915.)

[1]Stream	1903-04	1904-05	1905-06	1906-07	1907-08	1908-09	1909-10	1910-11	1911-12	1912-13	1913-14	1914-15	Mean
Sacramento	15,960,000	10,600,000	11,100,000	13,700,000	7,720,000	13,400,000	8,910,000	9,910,000	6,370,000	6,835,000	13,503,000	12,350,000	10,858,200
Stony Creek	753,000	508,000	535,000	765,000	338,000	894,000	351,000	535,000	127,000	[2]249,000	[2]820,000	[2]777,000	554,300
Feather	9,330,000	4,490,000	6,710,000	9,340,000	3,490,000	7,380,000	4,500,000	6,980,000	2,090,000	2,674,100	7,735,300	5,880,000	5,883,300
Yuba	4,100,000	2,400,000	3,630,000	4,560,000	1,590,000	3,880,000	2,670,000	3,510,000	1,130,000	1,397,200	2,865,300	2,500,200	2,852,700
Bear	[2]538,000	315,000	561,000	726,000	188,000	525,000	256,000	512,000	87,600	106,000	543,000	472,400	402,500
American	[2]5,046,000	2,460,000	4,762,000	5,710,000	1,450,000	4,540,000	3,540,000	6,480,000	1,260,000	1,433,700	3,949,600	3,061,300	3,641,000
Cache Creek	890,000	629,000	740,000	983,000	309,000	1,280,000	250,000	496,000	96,900	72,300	1,172,700	999,100	654,800
Putah Creek	[2]672,000	[2]475,000	583,000	691,000	199,000	881,000	228,000	483,000	56,300	133,500	895,300	709,700	500,600
Totals	37,229,000	21,877,000	28,621,000	36,475,000	15,284,000	32,780,000	20,705,000	28,906,000	11,157,800	12,900,800	31,484,200	26,749,700	25,847,400

[1]The "flow year" begins with the rainy season, and is registered from October 1st to September 30th following.

[2]The figures for Bear and American Rivers, 1903-1904, and Putah Creek, 1903-1904 and 1904-1905, are interpolated, and are obtained as a proportion of the recorded flow of the nearest neighboring watershed. They are not assumed to be correct, but are inserted to show probable totals for the years when the record was incomplete. The same is true for Stony Creek for years of 1912-1913, 1913-1914, 1914-1915.

NOTE.—Records since September 30, 1912, have not been published. The figures for 1912-1913, 1913-1914, 1914-1915 are provisional—subject to revision for purposes of publication.

TABLE No. 18.

Flow of Water in San Joaquin River Basin, October, 1907, to September 30, 1915.

Stream	Drainage area, square miles	Maximum flood flow, second-feet	Maximum mean daily flow, second-feet	Maximum monthly flow, acre-feet	Minimum monthly flow, acre-feet	Maximum annual flow, acre-feet	Minimum annual flow, acre-feet	Mean annual flow, acre-feet
San Joaquin	1,640	38,800	38,800	946,000	16,200	3,560,000	1,050,000	2,049,260
Merced	1,090	37,200	37,200	465,000	[1]3,040	2,120,000	440,860	[2]1,035,640
Tuolumne	1,500	52,600	52,600	821,000	3,900	3,410,000	1,050,000	2,000,520
Stanislaus	925	36,900	36,900	491,000	238	2,320,000	494,050	1,235,480
Calaveras	395	69,600	69,600	323,000	0	675,000	31,360	255,390
Mokelumne	642	16,700	16,700	331,000	3,960	1,530,000	393,000	847,690
Cosumnes	524	22,400	22,400	264,000	131	874,000	127,300	418,020
Totals		274,200				14,489,000	3,586,570	7,842,000

[1]October, 1913.

[2]Six-year mean.

TABLE No. 19.

Annual Flow of the San Joaquin River and Tributaries Expressed in Acre-feet for Each Year From 1907-1908 to 1914-1915.

Stream	1907-08	1908-09	1909-10	1910-11	1911-12	1912-13	1913-14	1914-15
San Joaquin	1,140,000	2,900,000	2,040,000	3,560,000	1,050,000	868,400	2,868,700	1,967,000
Merced	518,000	1,480,000	1,140,000	2,120,000	515,000	440,860	[1]	----------
Tuolumne	1,070,000	2,650,000	2,080,000	3,410,000	1,050,000	1,075,560	2,623,700	2,044,860
Stanislaus	598,000	1,890,000	1,370,000	2,320,000	587,000	494,050	1,584,360	1,045,460
Calaveras	[2]67,200	472,000	195,500	675,000	63,000	31,360	272,700	266,360
Mokelumne	480,000	1,150,000	906,000	1,530,000	393,000	423,000	1,076,700	822,800
Cosumnes	148,000	638,000	463,000	874,000	139,000	127,300	547,550	407,340

[1]Record discontinued.
[2]Record incomplete.

TABLE No. 20.

Flow of Streams in Tulare Lake Basin.

Seasonal year	Tule River				Kaweah River				Kings River				Total of three streams, acre-feet
	Discharge in second-feet			Total acre-feet	Discharge in second-feet			Total acre-feet	Discharge in second-feet			Total acre-feet	
	Maximum	Minimum	Mean		Maximum	Minimum	Mean		Maximum	Minimum	Mean		
1903-04	2,305	7	97	70,300	2,920	40	516	373,000	15,700	130	2,400	1,740,000	2,183,300
1904-05	822	7	99	71,000	2,730	40	466	388,000	9,795	150	1,970	1,430,000	1,889,000
1905-06	4,370	8	461	335,000	8,160	40	1,497	1,090,000	26,600	150	5,300	3,856,700	5,281,700
1906-07	2,300	28	214	154,000	3,400	75	820	594,000	15,800	330	3,790	2,750,000	3,498,000
1907-08	1,230	6	113	81,400	1,600	42	348	253,000	6,920	265	1,425	1,030,000	1,364,400
1908-09	5,070	21	397	285,000	9,210	51	1,110	800,000	20,300	265	3,890	2,810,000	3,895,000
1909-10	5,430	5	162	117,000	7,910	34	481	350,000	14,700	270	2,450	1,780,000	2,247,000
1910-11	2,780	9	168	121,000	6,610	39	755	546,000	20,500	196	3,900	2,830,000	3,497,000
1911-12	260	1	69	49,800	2,360	30	285	207,000	12,400	168	1,330	968,000	1,224,800
1912-13	248	1	40	29,200	1,470	32	305	111,500	7,210	136	1,300	941,800	1,082,500
1913-14	4,710	2	173	125,200	9,880	30	672	486,000	[1]30,400	186	3,520	2,548,400	3,159,600
1914-15	1,380	8	142	102,800	3,280	45	511	369,500	16,300	190	2,510	1,817,100	2,289,400
Mean 12 years			178	128,480			647	459,880			2,815	2,041,830	2,630,140

[1]Maximum flow at crest of flood, 62,000 second-feet.

KERN RIVER BASIN.

As stated above, this is the only stream in this region of sufficient importance to warrant a record of flow being secured. Gaging records were obtained of this stream by the State Engineering Department from 1879 to 1884. In 1893 the Kern County Land Company, which controls all of the waters of the river, established a gage at the mouth of the canyon, which has been maintained ever since. The records, which are furnished by the land company, show that for a period of 23 years the mean annual discharge of the stream was 804,000 acre-feet.

Other stations are maintained in the mountains by different power development companies who are engaged in or contemplate the development of power.

TABLE No. 21.

Flow of Kern River.

Seasonal year	Discharge in second-feet			Total acre-feet
	Maximum	Minimum	Mean	
1903-04	3,167	150	688	469,000
1904-05	3,089	194	756	548,000
1905-06	9,505	175	2,528	1,840,000
1906-07	4,504	433	1,606	*869,000
1907-08	2,080	272	900	*380,000
1908-09	8,851	249	2,300	1,630,000
1909-10	4,656	248	1,020	740,000
1910-11	4,623	248	1,384	1,000,000
1911-12	2,919	100	579	421,000
1912-13	1,826	136	494	357,800
1913-14	18,287	197	1,510	1,094,500
1914-15	4,249	225	917	664,000
1915-16	17,962	224	3,390	2,463,100
Mean, 13 years			1,394	959,700

*Records incomplete.

GROUND WATERS.

Although of the surface waters of the state, if all could be conserved and applied to the lands, there would be enough to irrigate all of the land requiring water, physical conditions are such that only a small portion of it can be utilized.

Many streams—those along the northwest coast, for instance—are in regions where little or no irrigation is required, and impassable mountains lie between them and the lands requiring water. Nearly all streams are subject to periods of diminished flow alternating with floods. Nearly, or quite all, of the latter must go to waste.

The streams of the state afford approximately 60,000,000 acre-feet of water annually, and while some is intercepted and carried upon the lands, and storage in reservoirs will enable more of it to be used, the lack of sufficient storage opportunities will always allow the great majority of the water to be dissipated.

All surface waters come from precipitation from the clouds in the form of rain or snow, which, falling upon the surface of the land, and descending its slopes, is gathered together into rivulets, brooks and rivers.

All of the precipitation, however, does not run off in visible streams, but part is absorbed by the soil, and always driven downward by the force of gravity, reaches untold depths in the earth. A portion again finds its way to the surface through natural springs, while still another portion may be recovered by means of wells.

Throughout many portions of the state large quantities of water are brought to the surface from wells, some flowing by hydrostatic force, others pumped.

Many large areas of land exist which can never be irrigated from any surface source, but often are underlaid with water-bearing strata, from which a supply may be obtained. Indeed, a number of prosperous communities have grown up from the profitable cultivation of the soil under irrigation from wells.

All of the cities, towns and homes throughout the San Joaquin Valley obtain water for domestic use from underground sources.

To ascertain the extent and accessibility of bodies of underground water then is a contemporaneous duty with that of investigating the surface supply. Responding to that duty the United States Geological Survey, in cooperation with the state and other public agencies, has been for several years prosecuting research into matters affecting the recovery of water from underground and applying it to use on the surface.

The first field of investigation after cooperation was established between the government and the state, was in the foothill belt of southern California, followed by examinations in San Joaquin Valley. In 1909 a report was published of research made in a portion of the Colorado Desert known as Coachella Valley. A report was also made of the underground resources of Antelope Valley, a part of the Mojave Desert. In 1912 surveys of underground water was begun in Santa Clara Valley and in Sacramento Valley, the results of which have been published.

Observations of the effects on the underground supply due to pumping and seasonal replenishment have been conducted for several years in southern California, the results having been published from time to time.

By the cooperation of the city of Los Angeles, exhaustive study was made of the underground storage in the detritus cones at the mouths of the streams entering Owens Valley from the Sierras.

The city and county of San Diego have cooperated in investigations of the water resources, underground and surface, of the county west of the mountain divide. The report will soon be published.

A comprehensive volume on the mineral and hot springs of California was published since the last report. A perusal of this interesting work is convincing that all the healing virtues of the famous spas of Europe are possessed by the waters of our own springs.

About 700 springs of various degrees of importance are described, scores of which were not known to the public until the publication of this report. It may be stated that by no means have all of these springs been developed as health or pleasure resorts, and undoubtedly many of those now unknown will some day become famous for their healing virtues.

A partial list of reports and publications treating of the underground waters of California, issued from the government press as "Water Supply Papers," follows:

W. S. P. No. 59. Development and Application of Water in Southern California, Part I. J. B. Lippincott. 1902.
W. S. P. No. 60. Development and Application of Water in Southern California, Part II. J. B. Lippincott. 1902.
W. S. P. No. 89. Water Resources of Salinas Valley. Homer Hamlin. 1904.
W. S. P. No. 112. Underflow Tests in the Drainage Basin of Los Angeles River. Homer Hamlin. 1905.
W. S. P. No. 137. Underground Waters in Eastern Coastal Plane of Southern California. W. C. Mendephall. 1905.
W. S. P. No. 138. Underground Waters in Central Coastal Plane of Southern California. W. C. Mendenhall. 1905.
W. S. P. No. 139. Underground Waters in Western Coastal Plane of Southern California. W. C. Mendenhall. 1905.
W. S. P. No. 142. Hydrology of San Bernardino Valley. W. C. Mendenhall. 1905.
W. S. P. No. 219. Ground Waters and Irrigation in Southern California Foothill Belt. W. C. Mendenhall. 1908.
W. S. P. No. 223. Preliminary Report on the Ground Waters of San Joaquin Valley. W. C. Mendenhall. 1908.
W. S. P. No. 225. Ground Waters of Indio Region (Coachella Valley). W. C. Mendenhall. 1909.
W. S. P. No. 278. Water Resources of Antelope Valley. H. R. Johnson. 1911.
W. S. P. No. 298. Water Resources of Part of Owens Valley. C. H. Lee. 1912.
W. S. P. No. 338. Springs of California. G. A. Waring. 1915.
W. S. P. No. 345-H. Ground Water Resources of the Niles Cone and Adjacent Areas. W. O. Clark. 1915.
W. S. P. No. 375-A. Ground Waters for Irrigation in Sacramento Valley. Kirk Bryan. 1915.
W. S. P. No. 398. Ground Waters of San Joaquin Valley. W. C. Mendenhall, R. B. Dole and Herman Stabler. 1916.

The cooperative investigations of underground water resources during the biennium ending June 30, 1916, were conducted under the direction of Mr. N. C. Grover, chief hydraulic engineer, water resources branch, and Mr. O. E. Meinzer, geologist, in charge, ground water division, whose report follows:

REPORT TO THE DEPARTMENT OF ENGINEERING ON THE PROGRESS OF THE GROUND WATER INVESTIGATIONS IN CALIFORNIA BY THE WATER RESOURCES BRANCH OF THE UNITED STATES GEOLOGICAL SURVEY FOR 1914-1915.

By O. E. MEINZER, Geologist in charge, Ground Water Division.

A comprehensive report on the springs of California by G. A. Waring was published as Water Supply Paper 338. It contains 410 pages of text and 17 illustrations, including a topographic and geologic map of California and a map showing the location and mineral character of the principal springs of the state.

The final report on ground water in the San Joaquin Valley, by W. C. Mendenhall, R. B. Dole, and Herman Stabler, was published as Water Supply Paper 398. It contains 310 pages of text, a map showing artesian areas and ground water levels in San Joaquin Valley, and other maps and diagrams.

The field work for the ground water survey of the Sacramento Valley, which was begun in September, 1912, was continued by Kirk Bryan, and was completed about January 1, 1915. A preliminary report by Mr. Bryan on ground water for irrigation in the Sacramento Valley was published as Water Supply Paper 375-A, and the maps and manuscript for the final report on the region were nearly completed. The preliminary report contains 49 pages of text and eight illustrations; it includes a map of the valley showing depths to ground water and a summary table of statistics of ground water irrigation.

Much progress was made by W. O. Clark in the ground water survey of the Santa Clara Valley, which was begun in August, 1912. A report on the ground water resources of the Niles Cone, which is a part of the Santa Clara Valley, was prepared by Mr. Clark and published as Water Supply Paper 345-H. This report contains 42 pages of text and a detailed map showing fluctuations of the water table, etc. It includes an estimate of the quantity of ground water annually available in the area. At the request of the Department of Agriculture, a special report was prepared by Mr. Clark on the ground water supply of the Morgan Hill area, which is also a part of the Santa Clara Valley. This report is to be published as a part of Water Supply Paper 400. Levels were run by L. F. Briggs to determine the altitude of observation wells in parts of the Santa Clara Valley.

Since 1900 measurements of depths to the water level in a series of wells in southern California have been made at intervals for the purpose of obtaining a record through many years of the relations between the contributions to the underground reservoirs in the rainy seasons and the withdrawals from them in the dry seasons, when ground water is pumped for irrigation and is withdrawn in large quantities by evaporation and transpiration. Most of the records for the period prior to 1909 have been published in Water Supply Papers 213 and 251; the records for 1909, 1910 and 1912, together with a brief discussion by W. C. Mendenhall, were published during the biennial period in Water Supply Paper 331. The work is at present being carried on by F. C. Ebert, who has selected companion wells and otherwise improved the methods. Mr. Ebert has also made progress in the tabulation of all available water level data for the region.

A survey of the ground waters in the San Jacinto Valley, begun several years ago by W. C. Mendenhall, was resumed by G. A. Waring, who did considerable additional field work and nearly completed the report on the area for publication as a Water Supply Paper.

An investigation of the ground water resources of the part of San Diego County lying west of the divide was begun by A. J. Ellis and C. H. Lee. Practically all of the field work and most of the office work were completed by June 30, 1916. The results are to be embodied in a comprehensive report on the water resources of the county. The water samples were analyzed by S. C. Dinsmore. Financial cooperation was furnished by the city of San Diego.

IRRIGATION INQUIRY.

In 1905, the state of California and the United States Department of Agriculture entered into a cooperative agreement for the investigation of subjects relating to irrigation and continuously since that time the investigations have been going on.

The United States is represented in this matter by the Office of Public Roads and Rural Engineering, formerly by the Office of Experiment Stations, while the Department of Engineering represents the state.

By cooperation with the college of agriculture of the University of California and the use of a portion of the University Farm at Davis, Yolo County, for experiments, the work is broadened and intensified to the mutual advantage of all concerned.

The subjects receiving particular attention in the investigations pursued are:

The duty of water as applied to different crops under varying conditions, and the factors which influence it.

Methods of irrigation with a view of securing better practice.

Methods and costs of pumping.

Loss from canals through seepage, evaporation and wasteful methods and the best means of reducing them.

The organization of irrigation enterprises, particularly irrigation districts and mutual water companies.

During the biennium just closed, special attention has been given to the study of duty of water in the irrigation of alfalfa. In addition to the experiments conducted on the University Farm, extensive observations and experiments have been conducted throughout the Sacramento Valley.

Alfalfa farms have been selected having widely different characteristics of soil, of drainage, of preparation and other features which affect the application of water and its influence on production. The quantity of water applied and its rate of application were measured. The movement of the water through the soil, the depth and rate of

penetration, and time of retention, all were ascertained. And finally the crop was weighed and the yield per acre learned.

All of the experiments demonstrate beyond question that at Davis the irrigation of alfalfa increases the yield according to the quantity of water applied up to a depth of irrigation of 36 inches; that the further application of 12 inches of water is without effect, while a still greater increase of irrigation water causes a decrease in crop yield.

The increase of crops due to each increment of water added from 12 to 30 inches is sufficient to insure additional profit for each irrigation, but the application of an additional six inches of water may cost as much as the profits on the slight increase of yield amounts to, while water applied beyond 36 inches may result in absolute loss.

Thirty to thirty-six inches in depth then is the limit of profitable application of water to the irrigation of alfalfa under the conditions of soil and climate found at Davis.

The experiments conducted extensively elsewhere show that the same law applies throughout the Sacramento Valley.

It may be argued that the results obtained as above stated would not apply in other regions, say in Oregon or Arizona.

It is admitted that under varying conditions the line of demarcation between profit and loss due to the quantity of water applied will not be exactly at 30 or 36 inches, but it is urged that no matter whether it be 20 inches or 48, or any other depth, the diagram illustrates a law that applies to the irrigation of alfalfa, and probably of all other crops, everywhere.

There is a quantity which can be determined within comparatively narrow limits which will give the best results. That limit the irrigator should know, and it is a duty of government to ascertain it for him—a duty the cooperating agencies mentioned are endeavoring to perform.

In studying methods of irrigation, considerable attention has been given since the last report to overhead irrigation by sprinkling.

The study of irrigation districts was concluded and the results were published as Bulletin No. 2 of this department and is reproduced in this volume as an appendix.

It might seem that the question of flood control is foreign to irrigation inquiry, but when flood waters can be directed upon porous, sandy lands into which the water can rapidly sink, losing or lessening its destructive force, and these same waters can afterward be recovered and used for irrigation, the solution of the problem of flood control contributes to the development of irrigation.

The success in Los Angeles and adjacent counties attending the practice of causing flood flows of streams from the mountains to forsake their channels and spread over the debris cones at the mouths of the canyons has been carefully investigated, and the application of the

principle to the flashy streams of Coachella Valley has been made the subject of study, a report upon which appears herein under the proper title.

Sanitary engineering is another subject that would at first thought appear to be outside the purview of irrigation inquiry, but since many communities have difficulty in disposing of their wastes, the study of the best methods of applying sewage irrigation is a proper subject for inquiry, and a systematic project has been outlined.

The great waste attending the operation of pumps for irrigation, a waste that is apparent to every engineer who gives even casual attention to the matter is being pursued, and plans are laid for more vigorous investigation of the subject in the near future.

Cooperative investigations into the various phases of irrigation during the past two years have been conducted by Frank Adams, irrigation manager in charge, under the direction of Samuel Fortier, chief of irrigation investigations, Office of Public Roads and Rural Engineering, United States Department of Agriculture.

The report of cooperative irrigation investigations, together with a comprehensive paper dealing with investigations of the economic duty of water for alfalfa in Sacramento Valley, and the report on flood control in Coachella Valley, hereafter presented as Appendixes C and D, respectively.

PROGRESS REPORT OF COOPERATIVE IRRIGATION INVESTIGATIONS IN CALIFORNIA, 1914-1916.

By FRANK ADAMS, Irrigation manager in charge.[1]

Cooperative irrigation investigations have been continued in California during the past two years along the general lines previously followed, the principal cooperating agencies continuing to be the United States Department of Agriculture, the California State Department of Engineering, and the University of California Agricultural Experiment Station.

On July 1, 1915, the irrigation investigations of the Department of Agriculture were transferred from the Office of Experiment Stations, Dr. A. C. True, director, to the Office of Public Roads and Rural Engineering, Logan Waller Page, director.

Investigations Under Way, 1914-1916.

The main field work of the past two years has been the completion of the studies of the duty of water for alfalfa begun in Sacramento Valley in 1910, and Imperial Valley in 1914.

The results of the work in Sacramento Valley are attached hereto entitled "Investigation of the Economical Duty of Water for Alfalfa in Sacramento Valley, California, 1910–1915."

This manuscript covers the cooperative experiments on the duty of water for alfalfa begun on the irrigation tract on the University Farm, at Davis, in 1910 and field studies relating to the same subject conducted on 54 alfalfa farms in Sacramento Valley during 1913, 1914, and 1915, and on a special experimental tract near Willows, during 1915.

Results of the work, both at Davis and on the Sacramento Valley alfalfa farms, have already been partly reported in reviews of the cooperative irrigation investigations during the two preceding bienniums printed in the third and fourth biennial reports of the Department of Engineering.

The results in Imperial Valley during the two-year period, 1914–1916, are now in course of preparation by Mr. C. E. Tait and Mr. Frank J. Veihmeyer; they are in part also being used in the preparation of a general treatise on irrigation of alfalfa in Imperial Valley, by Walter E. Packard, superintendent of the Imperial Valley Substation of the University of California Agricultural Experiment Station, with whom Messrs. Tait and Veihmeyer have been cooperating.

Other work under way during the past two years, with its present status, is outlined below:

1. *Study of irrigation Districts in California, 1887 1915.* Completed, October, 1915, and published as Bulletin No. 2 of the State Department of Engineering.

In addition to the study of irrigation districts in California, the gathering of information about irrigation districts in the other western states has been continued, the expenses of this latter work being paid only in part from the fund set aside for cooperative irrigation investigations in California.

[1] Under the direction of Samuel Fortier, chief of irrigation investigations, Office of Public Roads and Rural Engineering, United States Department of Agriculture.

2. *Study of Land Settlement Conditions in California.* This was started in the spring of 1914 and in part furnished a basis for the Land Settlement Bill (Senate Bill No. 509) considered in the last legislature. During the present season investigations have been conducted in cooperation with the State Commission on Land Colonization and Rural Credits, the college of agriculture of the University of California, and the Commonwealth Club of California, the participation of the California cooperative irrigation investigations during the season of 1916 being limited to informal cooperation with the agencies named.

3. *Investigations at Davis.* As heretofore, the cooperative irrigation studies and experiments carried on on the irrigation tract at the University Farm, at Davis, other than those relating to the duty of water for alfalfa above referred to, have had to do with the irrigation of and the duty of water for oats, wheat, barley, corn, potatoes, sugar beets, and orchards and vineyards, and with certain phases of the irrigation of alfalfa other than duty of water.

During the season of 1916 two experimental spray irrigation plants have been added to the equipment on the tract and experiments in the irrigation of vegetables by sprinkling have been begun in cooperation with the division of Olericulture of the Department of Agriculture of the University; also experiments in the irrigation of small fruits by sprinkling in cooperation with the division of Pomology.

With the close of 1915 the duty of water studies and experiments with the field crops mentioned as outlined in 1911 were completed and a full report of these experiments and studies, including experiments and studies for several previous seasons, has been prepared by Mr. S. H. Beckett, irrigation engineer, locally in charge at Davis, and is ready for publication. In the work at Davis, Mr. Beckett has been assisted by Mr. O. W. Israelsen and Mr. Roy Wray.

4. *Irrigation of Small Fruits in California.* Information along this line gathered from time to time, some years ago, has been worked over and supplemented by further field studies by Wells A. Hutchins, and his report thereon has been published by the college of agriculture of the University of California as Circular 154.

5. *Irrigation of Rice in Sacramento Valley.* Cooperation with the Bureau of Plant Industry of the United States Department of Agriculture was begun in 1914 at the Rice Experiment Station at Biggs, a preliminary report thereon having been submitted with the report of cooperative irrigation investigations, 1912–1914.

This cooperation has now continued during a three-year period, the subjects under investigation having been the duty of water for rice on a 40-acre field adjoining the experiment station, the depth of submerging the rice fields during the principal season of irrigation, the time of submergence with reference to planting and the emergence of the plants above ground, the temperature of the water in the rice fields, and the effect of stagnant water on the growth of the rice.

This work has been done under the immediate supervision of Mr. Ralph D. Robertson, irrigation engineer, who now has in preparation a practical farmers bulletin on rice irrigation in Sacramento Valley.

During the season of 1916 further data on rice irrigation and on the duty of water for rice have been gathered on 18 fields on the west and

east sides of Sacramento Valley in the general vicinities of Willows, Maxwell, Princeton, Nelson, Richvale, Biggs, Gridley and Marysville.

This latter study has been conducted under a separate cooperative agreement between the Office of Public Roads and Rural Engineering and the California State Water Commission, so that a report thereof will be submitted to that commission.

The work has, however, been supervised by Mr. Robertson, and the information gathered is also being used by him in the preparation of the farmers bulletin referred to.

6. *Irrigation of Orchards.* A scientific study of fundamental questions relating to the irrigation of orchards in California has long been needed, but funds have not been available for making it.

It is now hoped, however, to take up this work at once as one of the main projects of the investigations, and as a preliminary to doing so a reconnaissance was made during the season of 1916 of present practice in orchard and vineyard irrigation in northern and central California, and during this same period additional data have been gathered by Mr. C. E. Tait, irrigation engineer, on the irrigation of walnuts and citrus fruits in southern California.

There has been found to exist a wide variation in methods of orchard irrigation which is only partly due to differences in physical conditions, and what is needed is a thorough understanding of the effect of differences in soil moisture content on the different physiological processes of the trees and on the quantity and quality of the product.

The field is so large in California, conditions vary so widely, and so many different orchard fruits are grown here that many years will be required, together with a considerable fund for field expenses, to bring results commensurate with the importance of the problems involved.

7. *Pumping for Irrigation.* As pointed out in the report of cooperative irrigation investigations for the preceding biennium, pumping for irrigation has increased very rapidly in California in recent years, rendering it important that all possible wastes in the installation and operation of farmers' irrigation pumping plants shall be avoided.

A project has therefore been outlined in immediate charge of Mr. Milo B. Williams, irrigation engineer, looking to the practical field study of the problems involved.

During the present season a reconnaissance of irrigation pumping practice throughout the state has been made by Mr. Williams and Mr. S. H. Beckett, irrigation engineers, and this will serve as a guide to the questions it is of most importance to consider first.

Some of the wastes that should be overcome are the results of poor arrangement, excessive lift above the ground surface, and improper relation between lift, speed, and type of pump.

At present the principal work undertaken along this line will be done on a relatively few plants so selected as to give them the most value as demonstrations.

8. *Mutual Irrigation Companies in California.* The report covering this subject previously mentioned as being in preparation by Mr. C. E. Tait, irrigation engineer, is now practically complete and will be available for publication during 1917.

9. *Preparation of Land for Alfalfa Irrigation.* One of the most important of the early cooperative irrigation studies in California had

to do with the preparation of land for irrigation and methods of applying water, the results being published as Office of Experiment Stations Bulletin No. 145.

The data presented in Bulletin No. 145 were supplemented and revised in later farmers bulletins issued by the Department of Agriculture (Nos. 263, 373, 392, 399, and 404), but due to changes in methods and costs it has been found desirable to make further studies, alfalfa being first taken up.

Much new material regarding the preparation of land for alfalfa irrigation was gathered in the course of the study of the economical duty of water for alfalfa in Sacramento Valley previously referred to, but additional data on this subject have been gathered throughout California by Mr. S. H. Beckett, irrigation engineer, during 1916.

The writing of a new manuscript on the preparation of land for alfalfa irrigation has therefore been undertaken, the work being assigned to Messrs. S. H. Beckett and R. D. Robertson.

10. *Minor Cooperative Irrigation Projects at Davis.* In connection with the irrigation studies and experiments on the irrigation tract on the University Farm, at Davis, several subprojects have been started in cooperation with different divisions of the University Agricultural Experiment Station, those relating to the irrigation of small fruits and vegetables by the sprinkling methods having already been referred to.

Others now under way are: (*a*) Irrigation of vines, in cooperation with the division of Viticulture, the work being done on the small experimental vineyard planted on the irrigation tract in 1911; (*b*) irrigation of orchards and small fruits at Davis, in cooperation with the division of Pomology; and (*c*) small plat experiments on the effect of the flooding and furrow methods of irrigation on soil bacteria, in cooperation with the division of Soil Chemistry and Bacteriology.

Another subproject, partly carried on at Davis, has dealt with certain problems of irrigation physics, chiefly with a new method of determining the volume weight of soils "in place," this work being done in cooperation with the division of Soil Technology.

Special Reports.

Special reports have been made from time to time at the request of committees and local organizations.

The chief of these has been a preliminary report on conservation and control of flood water in Coachella Valley made at the request of local parties by Mr. C. E. Tait, irrigation engineer, under specific instructions of the director through the chief of irrigation investigations.

In this connection, and in order to be able to recommend to the Coachella Valley Storm Water District proper methods of controlling and conserving the storm waters menacing Coachella Valley, Mr. Tait made a careful investigation of the spreading of storm water in Santa Ana River, San Antonio Creek, Lytle Creek, and Santiago Creek, in Los Angeles and San Bernardino counties, and of the experiments with check dams made by officials of Los Angeles County in Haines Canyon.

Mr. Tait's report, fully illustrated, follows as Appendix D.

The other of the more important special reports prepared during the past two years, none of which has been intended for publication, have been as follows:

1. Report on the feasibility of the proposed South Santa Clara Irrigation District near Morgan Hill, Santa Clara County.

In this report, which was made with the assistance of Mr. S. T. Harding, irrigation engineer, the organization of the proposed district, with a view to providing means for a complete field investigation and report on the project, was recommended.

2. Report on the feasibility of a pumping irrigation project at Oakley.

This was merely a preliminary report to assist the people at Oakley in determining whether they should unite for a final survey. It was prepared by Mr. S. T. Harding, irrigation engineer, and showed that such a project as has been contemplated for the Oakley section is entirely feasible from an engineering standpoint.

3. Report on the feasibility of the proposed Cosumnes Irrigation District.

This report was made with the assistance of Professor T. Francis Hunt of the college of agriculture of the University of California, and among other recommendations made, was one for a more detailed soil survey prior to finally determining the best course to pursue.

Through the courtesy of Dean Thomas F. Hunt and Professor Charles F. Shaw of the college of agriculture of the University of California, this survey is to be made beginning about November 15, 1916.

Silt Determinations on Colorado River.

During the heavy floods in Colorado River in January and February, 1916, Mr. F. J. Veihmeyer, assistant irrigation engineer, took a number of samples of water from Colorado River at Yuma and from different points on Imperial and Yuma canals for making determinations of the amounts of silt carried. Additional samples were taken from Imperial Canal and from flooded fields in Imperial Valley during the summer.

All of these samples have been settled in tubes in Los Angeles and the results will later be used in connection with similar data previously collected from Colorado River and canals by Mr. C. E. Tait.

Sewage Irrigation.

Although not directly a part of the cooperative irrigation investigations in California, a project has been begun on sewage irrigation, under the immediate direction of Mr. Milo B. Williams, irrigation engineer. Mr. Williams is assisting a number of California cities and towns, and also the University Farm, at Davis, in working out better plans than are now followed in profitably utilizing sewage in irrigation, the expense of this work being almost wholly paid for from funds other than those allotted for cooperative irrigation investigations in California.

Lectures, Advice, and Assistance.

Members of the cooperative irrigation investigations staff have continued to be called on frequently to give lectures before local bodies and communities on irrigation topics, the number of such lectures given during the past biennium exceeding the number given during any

previous like period. Frequently expert advice, both in the office and in the field, has been called for and given to the extent practicable.

Irrigation Legislation.

As in previous years, assistance in drafting needed irrigation legislation has been rendered during sessions of the legislature at the request of the Department of Engineering and of members of the legislature.

In 1915 the principal work of this nature had to do with amendments to the California irrigation district act designed to make public regulation of irrigation districts commensurate with the obligation and responsibility of the state in the organization of irrigation districts, and in the issuance of bonds and the construction of works with the proceeds of such bonds.

Present Status of Irrigation in California.

The past two years have been a period of some improvement in the financial conditions of California irrigation projects, of some increase in the irrigated acreage, chiefly in Imperial Valley and in the rice fields of Sacramento Valley, and of the beginning of a number of new important irrigation projects.

The improvement in the financial condition of California irrigation projects has in part been reflected in the higher price received for irrigation district bonds and in part in the financial reorganization of several of the larger projects, such as some of those in Sacramento Valley that were started within the last ten years, but which found themselves unable to succeed according to the original plans of their promoters.

The area devoted to rice growing in California, relatively small down to 1914, increased to 32,000 acres in 1915, and to an estimated 63,000 acres in 1916, of which, in 1916, about 95 per cent has been in Sacramento Valley, with the remainder chiefly in San Joaquin Valley.

This new crop, and also the rapidly increasing acreage of cotton in Imperial Valley, estimated at 98,000 acres in 1916, including about 55,000 acres south of the state boundary, has brought forward for study and solution many irrigation questions that are new to California; and, in the case of rice, this new development has stimulated new construction or extensions of irrigation projects to a degree that is of great relative importance.

The construction within the past two years of the Great Western Canal, already one of the larger of the state's irrigation channels, would not have been feasible at this time except for the demands of rice irrigation, and needs of this crop on the west side of Sacramento Valley have been a considerable factor in facilitating steps toward the financial reorganization of the Sacramento Valley project.

The pending reorganization of this project so as to divide the area served by Central Canal into two irrigation districts aggregating 35,000 acres, an additional district or company of about 90,000 acres directly under Central Canal, and such other smaller divisions as are later needed to care for the remainder of the area under Central Canal, give promise of turning a very unsuccessful enterprise into one that can begin to succeed.

Of the irrigation districts recently formed in California construction is well advanced in Anderson-Cottonwood, Lindsay-Strathmore, and Carmichael districts, and construction plans are well under way in West Side (Tracy) and Terra Bella districts.

In the Fresno section the big water problem continues to be the working out of some form of organization of the six communities involved in the use of water from Kings River for the financing and construction of the proposed Pine Flat reservoir, and for the coordination of the requirements of both irrigation and drainage.

A solution of the problem has recently been brought nearer by the completion for the United States Reclamation Service of a thorough engineering study of the entire situation, both as it affects the late-season irrigation needs of much of the land now irrigated from Kings River, and the drainage needs of extensive areas of lands injured by the rise of ground water.

By a combined plan of constructing the proposed Pine Flat reservoir and of withdrawing water from water-logged areas, both in normal years and to carry over abnormally dry years, the way now seems open, under proper organization and financing, for caring for the needs of 800,000 acres physically tributary to Kings River and commercially tributary to the towns and cities of Fresno County.

In Los Angeles County the outstanding irrigation event of the past two years has been in connection with the development of San Fernando Valley. A temporary irrigation system was constructed to care for immediate irrigation needs, but the installation of a complete pipe distributing system to supply Los Angeles aqueduct water to 76,000 acres in Los Angeles County Water Works District No. 3, is now under way and well advanced, the total bond issue to cover its cost being $2,606,000.

In addition, plans are completed and some preliminary work has been done by the city of Los Angeles for a similar distributing system for 11,215 acres comprised in Los Angeles Municipal Improvement District No. 2, lying within Los Angeles in San Fernando Valley, a bond issue of $360,000 being pending to cover the cost of the improvement.

In Imperial Valley the chief events of interest have been connected with the final taking over of the Imperial Canal by Imperial Irrigation District, the ultimate form of control to be established, and the extension of the High-line canal on the east side of the valley to add a total of 130,000 acres to the area in the valley under ditch.

While Imperial Irrigation District was at last able to solve the intricate legal and financial questions involved in the transfer of the property from the creditors of the old California Development Company, it has not thus far succeeded in overcoming certain physical difficulties connected with maintaining an adequate water supply at all times.

As a result of these physical difficulties, and also because of the human problems involved in working out cooperatively such large questions as Imperial Valley presents, the proposal to seek some kind of a working agreement with the United States Reclamation Service has again come into first place before the people of the valley.

In the mean time consulting engineers have been employed to recommend a two-year program of reconstruction that will include, among

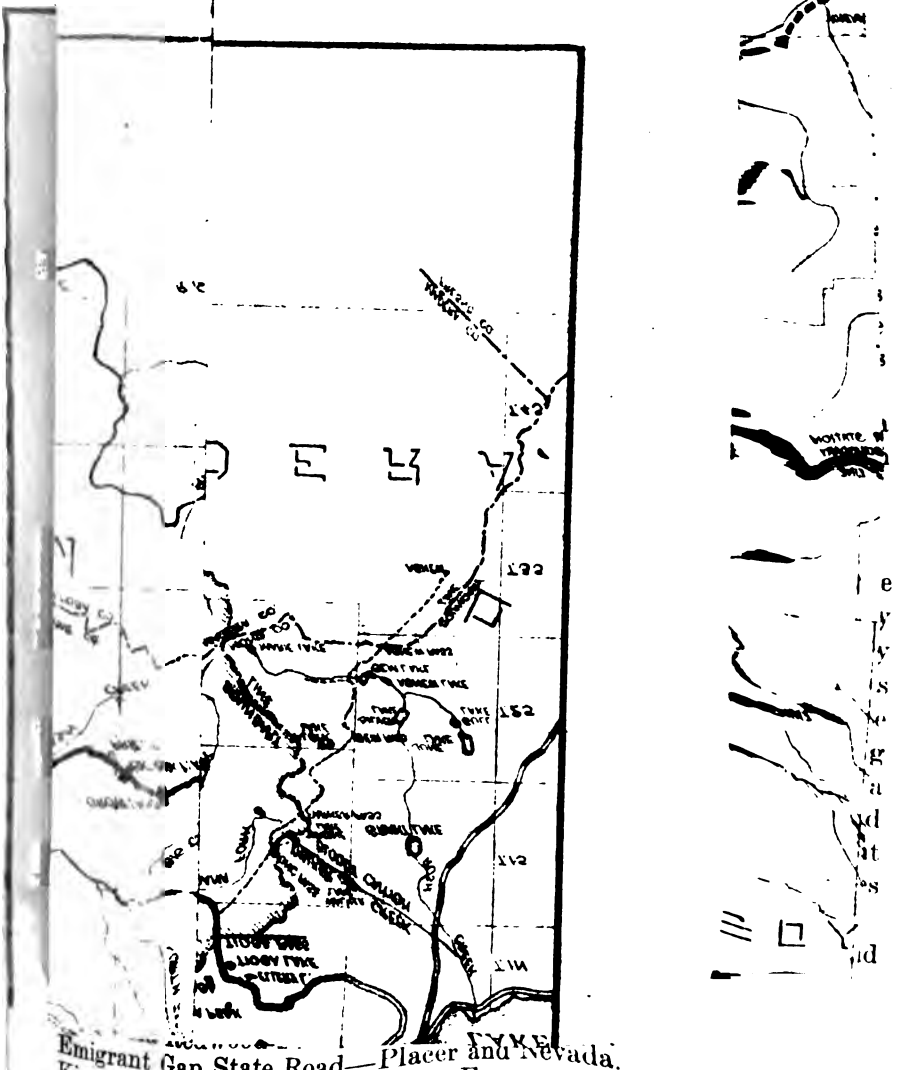
other things, a new heading in Colorado River, straightening of portions of the Alamo channel in Mexico, to add grade and reduce silting. strengthening of levees in the region of Volcano Lake, replacing of numerous structures and adding others, and some final decision regarding the extension of Cerro Prieto Canal.

PLATE XX.

A charming view from a scenic state road.

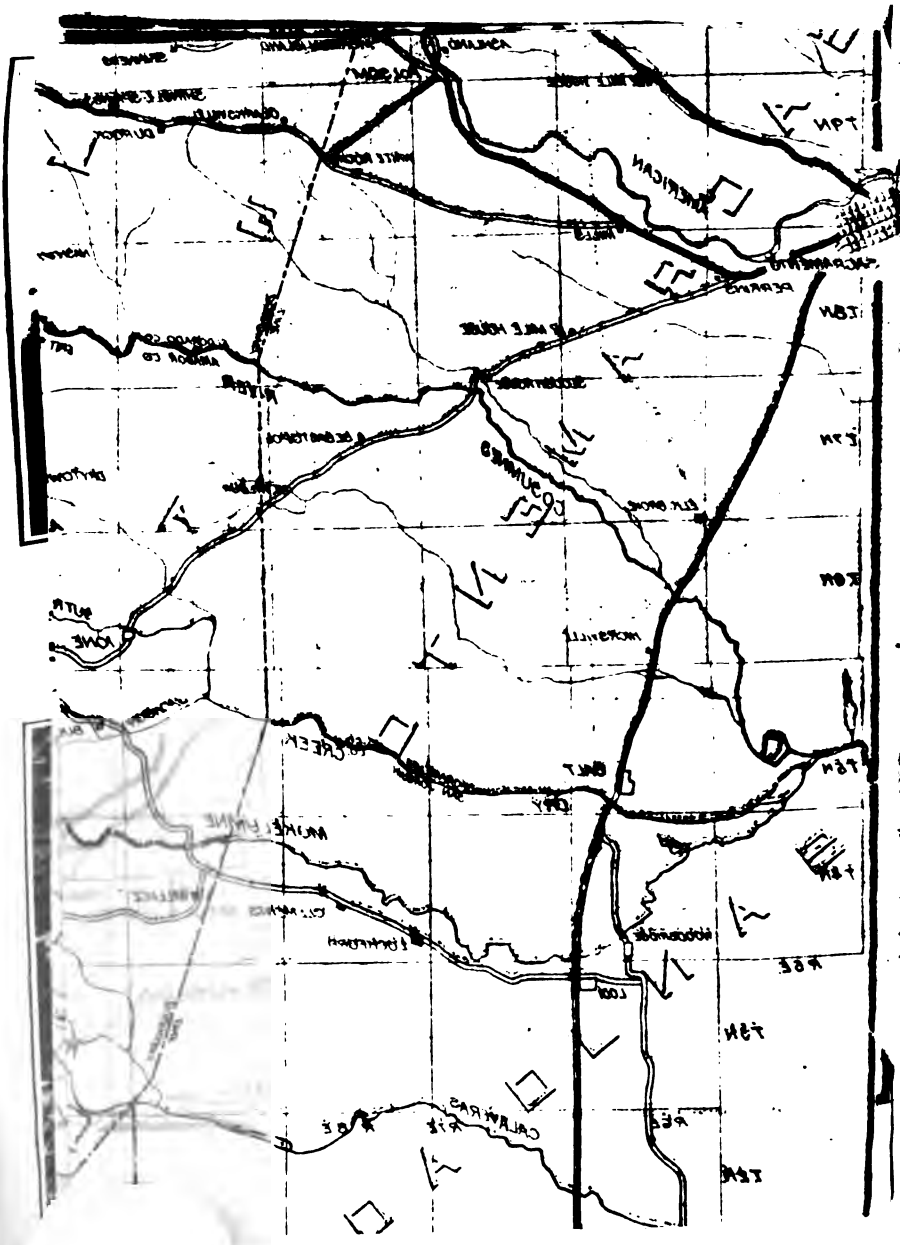
"Sleeping Waters"—Along a scenic state road.

PART III.



Emigrant Gap State Road—Placer and Nevada.
Kings River Canyon State Road—Fresno.
Lake Tahoe Wagon Road—El Dorado.
Lassen State Highway—Lassen.
Mono Lake Basin State Road—Mono.

PLATE XX.



"Sleeping Waters"—Along a scenic state road.

PART III.

STATE ROADS AND HIGHWAYS.

Two distinct systems of public highways are under state administration in California.

One system dates from 1895 when the legislature declared the road from Placerville, El Dorado County, to the state line near Lake Tahoe to be a state road, and created a commission to take charge of it. The other system was inaugurated in 1910 when the people voted a bond issue of $18,000,000 with which to construct a system of highways throughout the state. The fund so provided, and the construction of the highways thereunder, are administered by a branch of the Department of Engineering delegated for that purpose and designated the California Highway Commission.

For convenience in distinguishing the two systems of highways described above, the roads built or acquired with the proceeds of state bonds are designated state highways, while the roads of the other class are referred to upon the records of the department as state roads.

Leaving the discussion of the state highways for another article, a brief description of the state roads, and the work expended upon them during the last two years, is here presented.

State Roads.

The system of state roads, beginning with the acquisition by the state of the Placerville-Lake Tahoe road, as stated above, has been gradually extended from time to time by the taking over to state control of county roads and the construction of new roads in the mountainous regions where the building and maintenance of roads in condition for free travel would be beyond the financial ability of the counties supporting them. The system now embraces a number of roads, each created by a special act of the legislature, and bearing the name usually designated in the act creating it. These roads are situated in many different counties and aggregate about 700 miles in length. The official names and the counties traversed by them are as follows:

Alpine State Highway—El Dorado, Alpine, Mono, Calaveras and Amador.
Auburn-Emigrant Gap State Highway—Placer.
Big Oak Flat State Highway—Tuolumne and Mariposa.
California Redwood Park State Road—Santa Cruz and San Mateo.
Emigrant Gap State Road—Placer and Nevada.
Kings River Canyon State Road—Fresno.
Lake Tahoe Wagon Road—El Dorado.
Lassen State Highway—Lassen.
Mono Lake Basin State Road—Mono.

McKinneys-Donner Lake State Highway—Placer and Nevada.
Myers Station-McKinneys State Road—El Dorado and Placer.
Pasadena State Highway—Los Angeles.
Sierra State Highway—Sierra.
Sonora-Mono State Road—Tuolumne, Alpine and Mono.
Tahoe City-Crystal Bay State Highway—Placer.
Trinity-Humboldt State Highway—Trinity and Humboldt.

It will be observed that some of the foregoing are called "State Roads," while others are termed "State Highways." There is no reason why all should not be designated by the same term. Most of the names are long and cumbersome, several being compound and far from euphonious, while some are misleading as a designation of locality. Several of these roads traverse localities wherein were enacted much of the romance and tragedy of California's early history, and might appropriately bear names commemorative of those events. The further discussion of this subject will appear in another article.

The foregoing list of state roads is arranged alphabetically, but in the following descriptions they are arranged so the descriptions will appear in a regular sequence, according to the locality of the roads. For convenience, all roads under this division are referred to, in the records of the department, as state roads.

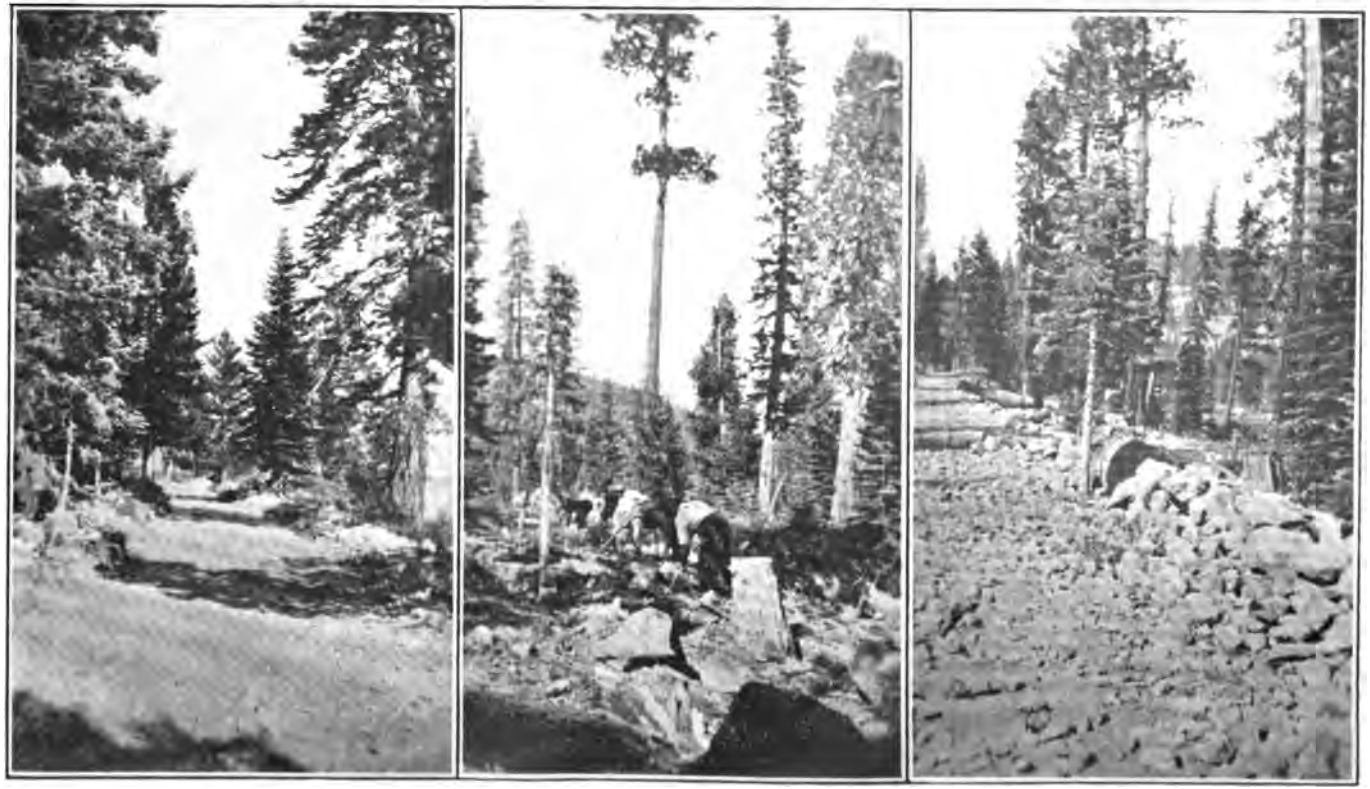
Kings River Canyon Road. Established 1906 by act of the legislature, to connect the roads of Fresno County at General Grant National Park with the famous Kings River Canyon, a rival of Yosemite Valley in scenic beauty and grandeur. The only means of access to this wonderful region is by pack trail. The surveyed length is 32.8 miles, of which 14.5 miles were built up to November 30, 1914, at a cost of $88,632 for construction and maintenance. No appropriation was made for this road by the legislature in 1915, but during the last period there was $5,958 expended for maintenance from the Motor Vehicle Fund. This road is under the care of J. E. Mitchell, superintendent.

Mono Lake Basin Road. The history of this road has been somewhat stormy and it is believed to warrant being set out at some length.

For many years the people of Inyo, Mono and Alpine counties had advocated the construction of a road across the Sierras, giving a direct route of travel between the communities on the east side of the mountains and the valleys on the west.

After the creation of the State Bureau of Highways in 1895 and its subsequent change into the State Department of Highways, renewed efforts were made to obtain the road. During 1896–7–8 the Highway Commissioners made examination of several mountain passes that were suggested and recommended the adoption of a route through Leevining Creek. In 1899 a commission was appointed by the Secretary of War to report upon roads for Yosemite National Park and the California

PLATE XXI. BUILDING STATE ROADS.



Third Stage—Completed. First stage. Second stage.

Commissioner of Highways was made a member of the commission. The joint commission inspected three routes across the range, viz: Leevining Creek Canyon, Bloody Canyon and Mill Creek Canyon, declaring the first-named to be feasible.

In 1899 the legislature appropriated $25,000 for the construction of a "free wagon road connecting Mono County roads with the Tioga road" and directed the Department of Highways to locate and construct the same.

The Tioga Road was a toll road built by a mining company to give access to the Tioga mine. It extended from the Big Oak Flat-Yosemite Valley road, near Crockers Station, up the Tuolumne River, past Tuolumne Meadows and over the summit to the mine. The length is approximately 64 miles. The Highway Commissioner was evidently not favorable to the Leevining route as he caused a survey to be made in 1900 of the Bloody Canyon route. A change in commissioners having occurred, in 1901 the Bloody Canyon route was abandoned and a survey made up Leevining Creek.

In 1902 a contract was let for the construction of 4.19 miles of the east end of the road. The contractor completed the work in 1903, but the commissioner refused to accept it on the ground that it did not conform to specifications. He retained $3,500 of the money claimed by the contractor, and in 1904 completed the work to his own satisfaction at a cost of $4,441.80, which was paid for out of the $3,500 retained and a $1,000 certified check the contractor had deposited in lieu of a bond.

In the mean time the legislature had appropriated another $25,000, and in 1904 a contract was let for the construction of the remaining 5.11 miles for the sum of $23,861. After completing about two miles of his contract the contractor failed and in 1909 the indemnity company which had furnished a bond for the contractor undertook to complete the contract, but in doing so they ignored the survey and selected a different route in places.

The company succeeded at a cost of $18,000 in building the road through to a connection with the Tioga road. The State Engineer who had succeeded to the duties of State Highway Commissioner refused to accept the road as constructed upon lines and in a manner not prescribed by the specifications. In February, 1912, a settlement was effected and final payment of $5,300.42 made, that being the balance remaining from the appropriation.

The cost to the state for construction and for maintenance during construction to the time of settlement was $58,210 and the loss to contractors about $17,000 more, making the total cost of 9.3 miles of road amount to $75,000.

The Tioga road was constructed by the Great Sierra Wagon Road Company, a subsidiary of the Great Sierra Consolidated Silver Company, who was engaged in exploiting the Tioga Mine. The road was built as a toll road under a franchise from the county of Tuolumne. Shortly after its completion the mine ceased to operate about 1882 or 1884, and that being the principal reason for building the road, and the only incentive to travel excepting by stockmen and a few hardy tourists who visit the high mountains in summer. The traffic over the road was small. Being charged toll on this road and also over the Big Oak Flat toll road to reach it, tended also to discourage travel.

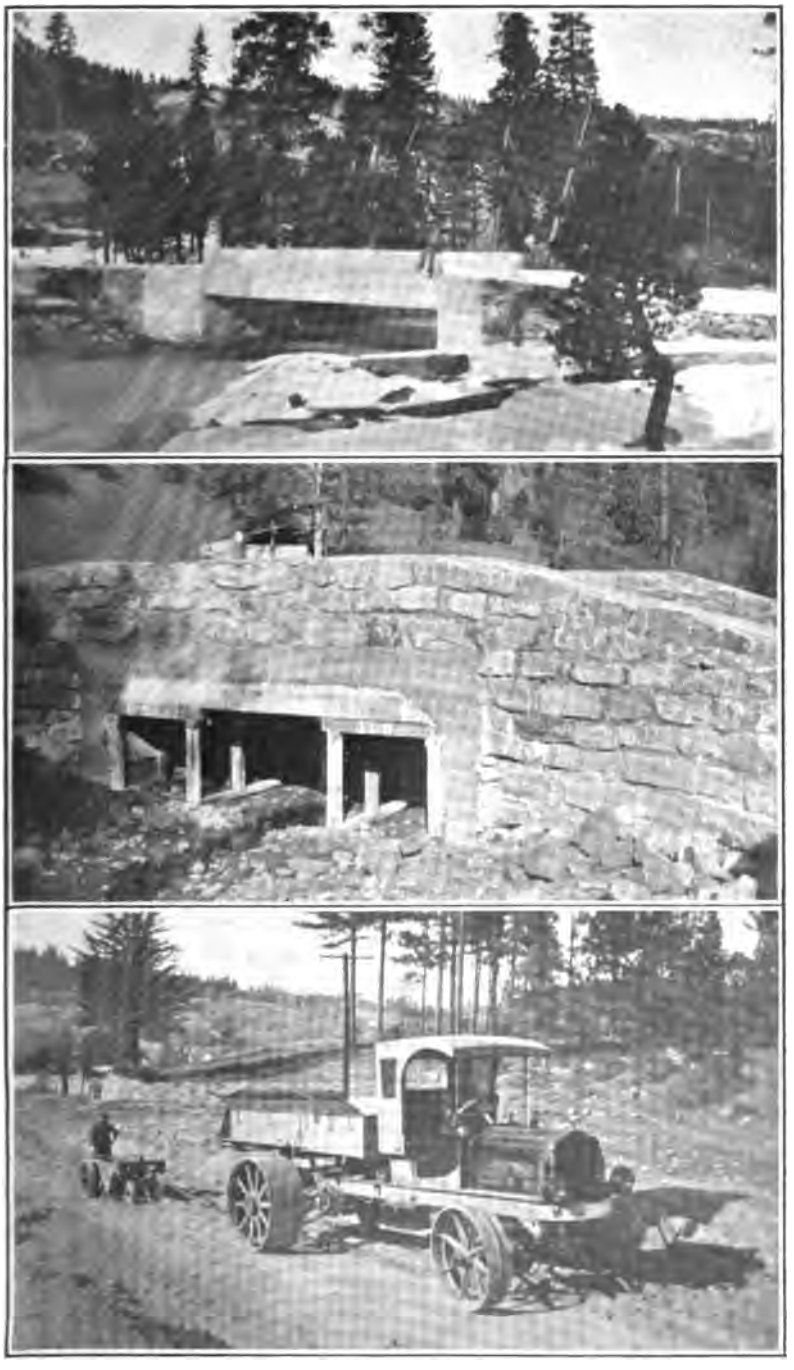
After travel to the mines ceased, the amount paid for tolls was insufficient to maintain collectors, hence the road received but little attention from its owners. Occasionally fallen timber was removed, and perhaps the worst washouts repaired so that the road was kept measurably passable for teams, and a few availed themselves of the shorter route from Mono Lake Basin to the interior valley.

Fifty-three miles of the road traverse the Yosemite National Park and in 1915 the government acquired it as an asset to the park, and the state legislature appropriated $3,000 for the purchase of that part of the Tioga road, approximately seven miles in length, lying between the park boundary and the Big Oak Flat road. (Chap. 306, 1915.) A requirement of the act was that the county of Tuolumne should terminate the franchise of the toll road company.

At the same time another act was passed (Chap. 396, 1915) declaring the Big Oak Flat toll road, 32 miles long, from Jack Bell sawmill to Cascade Creek, a state highway. To become effective the act required the county of Tuolumne to acquire the road and transfer it to the state and also to set over to the state the county road connecting the Big Oak Flat road with the Tuolumne lateral of the state highway near Chinese Camp. All of these requirements being met, the road extending from the Valley Trunk State Highway between Stockton and Modesto to Mono Lake, is now a state highway excepting the link of 53 miles through the Yosemite National Park, which is maintained by the park authorities.

In addition to the transmountain road operated by the state and government, by the acquisition of the Big Oak Flat toll road, the state has acquired a branch or spur road extending from Sequoia, through the Tuolumne Big Tree grove, 14 miles to Cascade Creek, within about five miles of the wonderful Yosemite Valley. About eight miles of this road is inside the Yosemite National Park. The extension of the road from Cascade Creek to Yosemite Valley is under the jurisdiction of the park superintendent.

PLATE XXII.



Reinforced concrete bridge. Rustic rock culvert.
Tractor breaking old road with a scarifier.

(p. 178)

The total distance from the state highway near Chinese to Mono Lake is approximately as follows:

Chinese to Big Oak Flat Road	27 miles
Big Oak Flat Road to Sequoia	19 miles
Sequoia Park line	7 miles
Park line to Tioga Pass (Government Road)	53 miles
Tioga Pass to Mono Lake Basin Road	1 mile
Mono Lake Basin Road	9 miles
Total	116 miles

To connect this road with the Sonora-Mono state road at Bridgeport will require the acquisition and improvement of about 34 miles of county highway now in fair condition.

All of this distance excepting five miles in Leevining Creek Canyon is included in a proposed state highway connecting Bridgeport, Mono County, and Independence, Inyo County, which will be constructed following the approval of the new $15,000,000 bond issue for state highways.

Since the state acquired the Tioga and Big Oak Flat toll roads connecting the state highway system with the Mono Lake basin state road, much work has been done in construction and improvement. This work has been done under the direction of Superintendent E. E. Newell, while W. H. Stone is in charge of the Mono Lake basin division, the costs being met by allotments from the Motor Vehicle Fund.

Sonora Mono State Road. This was formerly a toll road extending across the mountains from Sonora, Tuolumne County, to Bridgeport, Mono County. In the days of mining activity in Bodie it was a very active thoroughfare, but with the decline of travel to the mines, it ceased to be profitable as a toll road, and in 1901 the legislature declared that part of it beginning at Long Barn, 20 miles from Sonora, a state highway. No appropriation was made for the road, and as the owners had sadly neglected it the road was in a very deplorable condition. Nearly all bridges and culverts were decayed and the roadbed itself was in bad condition.

In 1903 the sum of $4,000 was appropriated for maintenance for two years, but with 78 miles of dilapidated road to rebuild, the appropriation could go but a little way. It was estimated that repairs to the road would require the construction of 258 culverts, 26 small bridges, four larger bridges of 35 to 75 feet span, with grading and other work, entailing an expense of $26,000.

In 1905 the legislature appropriated $28,000 for improvement, maintenance and repairs. A power company was engaged in constructing reservoirs in the Tuolumne River canyons, and to expedite its work, rebuilt 38 miles of the road from Long Barn without cost to the state. With the funds appropriated and a further appropriation in 1907 of

$12,000, the remaining 40 miles was greatly improved, including the construction of a steel truss bridge of 70 feet span over West Walker River, and a concrete bridge over the East Fork, besides two other reinforced concrete bridges of 18 and 20 feet span, respectively.

Superintendent L. C. Chase has been in charge of the improvement and maintenance of the west division of this road from Long Barn to Summit and Superintendent C. M. Stewart has had charge of the work on the east division from Summit to Bridgeport. The moneys for maintenance of this road are obtained from the Motor Vehicle Fund.

Alpine State Road. In 1911 the legislature passed an act by which a number of roads traversing Calaveras, Amador, Alpine, Mono and El Dorado counties were declared a state highway. These were roads constructed by the counties or by toll road companies and afterwards acquired by the counties, and aggregate 217 miles.

For convenience the Alpine road is divided into four divisions, as follows:

Alpine road, from Osgoods, on the Tahoe state road, through Markleeville to Mount Bullion.

Calaveras branch, from Calaveras Big Trees Grove, through Ebbetts Pass to Mount Bullion.

Amador branch, from Jackson, Amador County, by way of Carson Pass, to connect with the Alpine road at Picketts, in the lower end of Hope Valley.

Mono branch, from Little Antelope Valley to a connection with the Sonora-Mono road, at junction on East Fork of West Walker River.

A section 24 miles in length between Mount Bullion and Little Antelope Valley has never been constructed. A survey was made in 1912, which indicated that instead of running from Bullion by way of Loop to Silver King Valley, a better route is up the Carson River to Silver King Valley.

If this road from Calaveras branch to the Alpine road in Antelope Valley were constructed it would enable travel to go to Bridgeport via either Tioga or Sonora-Mono road and return by Calaveras or Amador, or continue on to Lake Tahoe, where the choice is offered of returning to Sacramento Valley by the way of Placerville or Truckee and Auburn, and all without leaving the state. Until that link shall be completed, one must go into Nevada in order to pass between Mono and Alpine counties.

No appropriation was made for maintenance and improvement of the Alpine state roads by the legislature of 1915. During the two years last passed, such work has been executed with moneys allotted from the Motor Vehicle Fund, as follows: repair and reconstruction of road bed; improvement of grade and alignment, and construction of bridges and culverts.

PLATE XXIII.

The kind of culvert before the state takes over a road.

The kind of culvert the state builds.

The four divisions of this road are under the supervision of the following-named superintendents:

Alpine trunk from Osgoods on Placerville-Tahoe road to Picketts, Woodfords, Markleeville and Bullion; Ebbetts Pass branch from Bullion to Pacific Valley; Carson Pass branch from Picketts to Silver Lake is under Grant P. Merrill. The Carson Pass branch from Jackson to Silver Lake is in the care of L. H. Cook; F. W. Mathews has charge of the Ebbetts Pass branch from the Big Trees to Pacific Valley; while the Mono division, from Antelope Valley to Junction on the Sonora-Mono road is under the care of C. M. Stewart. These men have been in charge of their respective divisions for several years, and the growing popularity of these roads with the summer tourist testifies to the quality of the work accomplished by them with limited funds and under unfavorable natural conditions.

Frosts and snow slides in winter and cloudbursts in summer play sad havoc with the roadways, requiring constant and sometimes strenuous effort to repair the damage.

The work of maintaining a mountain road in the condition required for comfortable automobile travel requires the faithful application of knowledge which can be gained only by experience, such as the road force of the department possesses.

Lake Tahoe-Placerville Road. This road was the first mountain road acquired by the state. It was originally a toll road incorporated as the Lake Tahoe Wagon Road. It began near Smiths Flat, three miles east of Placerville and extended over the mountain, for the most part following the overland stage route to the state line near Lake Tahoe. It was declared to be a state road by act of the legislature, approved March 23, 1895. (Chap. 128–1895.) For several years this road was cared for by the Lake Tahoe Wagon Road Commissioner at a salary of $300 a year. Biennial appropriations were made for its maintenance, but they were not large enough to permit much improvement to be effected.

In 1899 the sum of $25,000 was appropriated to repair and rebuild the road, build bridges and make a survey of it. A stone bridge 81 feet long, across the American River, was completed in 1901. The commissioner at this time was receiving $50 a month.

In 1905 the legislature appropriated $15,200 for salary, maintenance and bridges.

In 1907 the Department of Engineering took over the management of the road, completed a stone bridge partly constructed over Trout Creek, and finished making a survey of the road.

The survey is marked by concrete monuments set below the road surface at intervals of 1,000 feet along the center line of the road. Granite mile stones, marked to designate the distance, are set conspicuously by the roadside. These stones are 6x18 inches by 54 inches long, and were cut and marked in the state prison at Represa.

Constant improvement of the road has been progressing ever since the department took charge. Several miles at the lower end are sprinkled daily during the summer.

In 1915 the legislature passed an act extending the state road from Smiths Flat to Placerville, where it connects with the El Dorado Lateral of the state highway system. The total length from Placerville to the state line is 65 miles.

Myers-McKinney State Road. Myers Station on the Placerville-Tahoe state road is in Lake Valley, some eight or nine miles south of Tallac, a summer resort on the lake shore. Prior to 1913, tourists desiring to pass from one end of the lake to the other by teams or automobile, were compelled either to ferry 30 miles on barges, which was uncomfortable and dangerous, or drive to Carson and Reno, Nevada, to Truckee, and then back to Tahoe, a distance of about 100 miles.

In 1911 the legislature appropriated $25,000 to make surveys and construct a road from Myers Station to the lake shore and around the west side of the lake to McKinneys, a resort on the west shore and the end of a road leading to Truckee. The road, 27½ miles long, was opened to traffic in 1913, though not completed until later.

Improvement has been expended upon the road every summer until it is now a very popular scenic way, skirting the shores of the lake above the bluffs. Much remains yet to be done in widening turns, but this is being done as rapidly as funds are provided.

The Lake Tahoe and the Myers-McKinney state roads are in charge of Superintendent H. L. Leventon.

McKinneys to Donner Lake. In 1915 the legislature declared the road running from McKinneys to Tahoe city, and thence to Truckee and the west end of Donner Lake, a state road. No appropriation was made. As soon as the transfer could be completed the Department of Engineering took charge of maintenance and improvement.

The road connects with the Myers-McKinneys state road at the south end and with the Emigrant Gap state road at Donner Lake.

Tahoe-Crystal Bay Road. The legislature, in 1915, made provision, by appropriating $3,000, for the survey and construction of a state road along the north shore of Lake Tahoe from Tahoe city to the state line at Crystal Bay. The road has been surveyed and with the appropriation provided, supplemented by $3,000, furnished for the purpose by Placer County, a considerable portion has been constructed. When completed, this road will enable one to travel entirely around Lake Tahoe in California over state roads.

Emigrant Gap Road. This road begins at Emigrant Gap, on the ridge between Bear and American rivers, and extends thence along the route traveled by the ill-fated Donner party and other immigrants coming into California in pioneer days, through Donner Pass to the

PLATE XXIV.

A rugged scene on state road.

Eagle Falls, from state road.

(p. 182)

west end of Donner Lake. Here it connects with the state road to Lake Tahoe established by legislative action in 1915. The same session of the legislature also declared the road from Emigrant Gap to Auburn a state road, so that now the Emigrant Gap road really extends from Auburn to Truckee over the route traversed by the old emigrant trail.

The original Emigrant Gap state road was taken over by the state in 1909. (Chap. 224–1909.) Most of the roadbed was built by the Central Pacific Railroad to facilitate construction in that stupendous undertaking. After the railroad abandoned it, the county maintained it as a county highway. The roadway was narrow with many steep and rocky stretches. The bridges were all wooden and badly dilapidated when the state took it in charge. These have been mostly eliminated by the construction of concrete bridges and concrete or iron culverts, throughout the old Emigrant Gap road, and the same treatment is being applied to the extensions—east to Truckee and west to Auburn.

Mr. E. M. Baxter, who has been in charge of the Emigrant Gap road for several years, is superintendent and directs the work over the entire route from Auburn to Truckee, from Truckee to Tahoe City and Crystal Bay, and from Tahoe City to McKinneys.

The most notable improvements effected on the Emigrant Gap road this biennium was replacing two dilapidated wooden bridges over the South Fork of Yuba River and one over Castle Creek with substantial reinforced concrete bridges, and the substitution of several concrete culverts for wooden structures.

Several other culverts and small bridges will be built during the months when little travel will interfere with the work, so that the traveler of next season will have little to complain of in the matter of "rickety" culverts.

Sierra State Highway. This road was authorized by act of the legislature in 1907, at which time $12,000 was appropriated to make surveys and construct the road. It is defined as running from Downieville to Mount Pleasant, a distance of 20 miles. About 14½ miles have been surveyed, and in 1908 there were constructed 2.9 miles beginning at Dowieville, at a cost of $8,018.97. The remainder of the fund was exhausted in surveys and in maintenance, the last of the money being used in 1912. There have been no appropriations or expenditures upon the road since the last named date.

This road would be about 20 miles long if completed. Less than three miles have been constructed at a cost of nearly $12,000. In its uncompleted condition it does not afford convenience to any considerable number of people and if completed would not connect any important centers of population or industrial activity; nor will it afford Downieville a good means of reaching the Sacramento Valley.

It is not considered by this writer to be a desirable road to maintain and it is believed that it should not be maintained unless completed. The suggestion is here made that the road be abandoned as a state road.

Lassen State Road. By act approved April 22, 1911, the legislature declared the county road beginning on the boundary line between Lassen and Shasta counties in the northeast corner of T. 37 N., R. 6 E., and running thence to the Lassen-Modoc County line in T. 38 N., R. 8 E., a state road. The road as described originates in Fall River Valley, runs northeasterly via Pittville and Bieber and up Big Valley to the county line a few miles below Adin. The length is 29 miles.

The act establishing it appropriated $5,000 for improvement and maintenance. No records are available of how the money was expended, but no doubt some benefit was received from the expenditure of the appropriation.

Since the present administration assumed charge, no appropriation has been made but considerable work has been expended in improvement and maintenance, the costs being met from the Motor Vehicle Fund. This work is under the supervision of Superintendent H. E. Wood.

Trinity and Humboldt Road. This road was provided for first by an appropriation in 1903 of $1800 for a survey of a road from North Fork, Trinity County, to some point at or near China Flat, in Humboldt County. A survey of 22 miles of the route was made, exhausting the appropriation so that the remaining 22 miles was left unsurveyed. In 1907 an appropriation of $50,000 was made for a road connecting the roads of Humboldt County with those of Trinity, Shasta and Tehama counties. Several routes were considered, each of which had strong advocates, but financial considerations finally led to the selection of the "Mad River Low Gap" route.

Construction was commenced in 1909 and on October 3, 1912, the first automobile passed over the road. Although open to traffic, the road was not completed for another year and even then was not supplied with bridges over South Fork of Trinity River and Mad River, which were built by contract in 1915. Both bridges are of the steel deck-truss type on concrete piers.

This road is 33 miles long, connecting the road systems of Humboldt and Trinity counties, and gives the shortest communication between Humboldt County and the Sacramento Valley, as well as giving the southern part of Trinity County access to the county seat, which, before this road was completed across South Fork Mountain, was possible only on horseback.

No appropriation was made for improvement and maintenance of this road at the last legislative session, but funds were allotted from

PLATE XXV.

A tourist's camp on state road.

Construction camp on a state road.

the Motor Vehicle Fund with which Mr. W. J. C. Dinsmore, superintendent, has continued that line of work.

California Redwood Park State Road. In 1913 the legislature provided for the location and construction of a state highway from Saratoga Gap, on the boundary between Santa Clara and San Mateo counties, through the mountains to the California Redwood Park in Santa Cruz County. Seventy thousand dollars was appropriated and the road was completed in time for the summer travel to the park in 1915.

Most of the roadway is of a nature that it works up into deep dust under wheel traffic and a large part of the cost of maintenance is due to the sprinkling required.

No appropriation has been made for maintenance, but allotments from the Motor Vehicle Fund enable the department to keep the road in good condition.

Mr. W. H. Dool, warden of the California Redwood Park, has had charge of this road since its completion.

Projected State Roads.

In addition to the state roads already established as enumerated above, the legislature has declared for certain other roads to be constructed as state roads, ordered the survey and location of them, but provided no funds for their construction. It is assumed that the intent of the several acts was to later make appropriations for construction, based upon the estimates to be furnished from the surveys.

These projected roads are described as follows:

Yolo and Lake Highway. Chapter 283, statutes of 1915, recites as follows:

> Section 1. A highway commencing at the town of Rumsey in the county of Yolo, state of California, and following generally the meanderings of Cache Creek, along the most practical and feasible route to the town of Lower Lake in the county of Lake, state of California, and to be known as "Yolo and Lake Highway," be and the same is hereby declared and established.

It will be observed that the foregoing declares and establishes a "highway" but not a state highway.

Three thousand dollars was appropriated to make surveys and investigations necessary for the location of the said highway, but no appropriation was made for construction.

A survey has been made following the general route specified in the statute, starting at Rumsey. The total length of the surveyed line is 35 miles. The construction will involve 126 acres of clearing, about 872,000 cubic yards of excavation, 170 culverts from one to eight feet wide and eight bridges aggregating 190 feet in length, the longest being 60 feet.

The total cost of constructing the road as surveyed is estimated at $175,000.

Kern-Ventura State Highway. An act of the legislature, approved June 12, 1915, appropriated $8,000 for the survey and location of a state highway from a point in Kern County south of Bakersfield to the town of Nordhoff, Ventura County.

At the date of this writing the survey is in progress and will be completed in time to submit estimates of the cost of construction for the consideration of the legislature this winter.

Pasadena State Highway. Chapter 704, Statutes of 1915, appropriated $7,500 for the location and survey of a state highway to connect La Cañada Valley with Antelope Valley in Los Angeles County, to be known as the Pasadena State Highway. The route laid down by the statutes for a survey begins about two miles northeast from La Cañada and running thence northerly and northwesterly along Arroyo Seco to a point east of Hoyt's Ranch, thence northeasterly by way of Tujunga Canyon and Mill Creek to Tie Canyon, thence by way of Kennedy Springs to Vincent.

The survey for this road is in progress at the date of this writing and will soon be completed so as to have estimates of cost of constructing the road for the information of the coming legislature.

State Aid Roads.

In addition to the state roads and highways established by special acts of the legislature as above described, there have been occasions when the legislature appropriated funds for survey, construction or improvement of certain roads without designating them as state roads. In fact, in at least one instance the act specified that the county should assume responsibility for the maintenance of the road after it had been completed.

Alturas and Cedarville Road. Chapter 192, approved March 11, 1907, appropriated $7,000 "for aid to the county of Modoc in the construction of permanent work on the county road between Alturas and Cedarville," placing the construction under the direction of the State Highway Commission. The appropriation was made contingent upon Modoc County having first spent $3,500 upon permanent work. The funds were expended during 1907 and 1908, since which time the county has had entire charge of its maintenance.

Middle Lake Highway. Chapter 765, Statutes 1915, appropriated $20,000 for the location and construction of a highway across Middle Lake in Surprise Valley, Modoc County. The road is about two miles in length, crosses the lake and connects at the east end with a county road "leading into Nevada." The soil is not suitable for a roadbed, and can withstand neither wheel traffic nor wave wash. To protect it

PLATE XXVI.

Sidehill grade on Pescadero-Redwood Park Road.

Sidehill grade on Pescadero-Redwood Park Road.

PLATE XXVII.

Typical county highway bridges on improved roads.

the roadway was raised above the flood height and riprapped on the slopes with loose rock, the same material being used to metal the surface.

All the rock had to be hauled from the hills some six miles distant by teams. The appropriation was exhausted before the work was completed and a portion remains in an unprotected condition.

This road was not declared by the statute to be a state road, and must be maintained by the county.

Pescadero-Redwood Park Road. The legislature, in 1915, passed an act reciting: "That a highway shall be constructed from Pescadero in the county of San Mateo to the California Redwood Park in the county of Santa Cruz. The responsibility of the state of California in the location, survey, construction and maintenance of said highway shall cease with the expenditure of the appropriation herein contained."

Ten thousand dollars was appropriated for the survey, location and construction of the road, and made contingent upon the Board of Supervisors of San Mateo County pledging the county to complete and maintain the road. This pledge having been made and also a similar pledge by the supervisors of Santa Cruz County, a survey was made and the road partly constructed during the summer of 1916.

The road as located begins at the county highway at the mouth of Butano Creek about four miles from Pescadero, and follows, generally, up the ridge between Butano and Little Butano creeks, to a connection with a county road in Santa Cruz County, near the summit between Butano and Waddell creeks, which, in turn, connects with the Saratoga-Park state road near Bulls Spring.

A survey was made of a route from the summit down Waddell Creek to the center of the park, which it is recommended should be constructed as being shorter and better than the Santa Cruz County road.

Under the terms of the act the completion of the road and its maintenance thereafter devolves upon the county of San Mateo.

The road, when completed, will afford a very delightful "loop" drive, enabling one to motor from San Francisco and the cities on the peninsula, down the Ocean Boulevard, thence by the new road through redwood forests to Redwood Park, returning by the state road to Saratoga and back by way of the state highway.

The estimated cost of completing the road under discussion as located is $35,000 to the summit and down Waddell Creek to the hotel at Governor's Camp.

In concluding the subject of state-aid roads, the Department of Engineering questions the wisdom of appropriating public funds for construction or improvement of roads over which the state will exercise no control in the matter of maintenance.

In the last case above discussed, not enough money was provided for building a road connecting any two accessible points. Several miles

yet remain to be constructed before that built from the appropriation can be of any use. It is true that San Mateo County is pledged to complete the road, but to do so with the high standard of construction adopted by the state will entail a heavy burden upon the county, and in such cases the natural tendency is to comply with the terms of the agreement by using a cheaper type of construction not in keeping with the state's work.

While upon the subject of state roads, it is desired to call attention to a matter which must soon be given serious consideration by the legislature. While good roads are built and poor roads improved for the benefit of all the people and everyone has an inherent right to their use, such use must be exercised with due regard to the rights of all others. Among those rights is the one to have the best of condition of roadway maintained at a minimum of cost.

Recent developments of motor transportation tend toward increasingly heavy loads and increased speed of travel, both of which entail immense burdens upon the maintenance of the roads.

A rapidly moving five- or ten-ton truck traveling 12 to 20 miles an hour, on the wheels that are usually provided for such vehicles, will do more injury to the surfacing of a road in a week than will occur from other traffic in several months.

If the cost of maintenance of improved roads is to be kept down to a reasonable figure there must be a limit placed upon the character of traffic allowed upon them. A just relation must be prescribed between the load, the width of tire, the speed, and perhaps also the size of wheel.

The same principle applies to the heavy freighting wagons used in the mountain roads. It costs more to repair the damage done to a few miles of mountain road traveled by heavy narrow-tired wagons during the summer than all the remainder of the roads not subjected to that traffic.

This is a question that is becoming acute and earnest consideration of it is commended to the legislature.

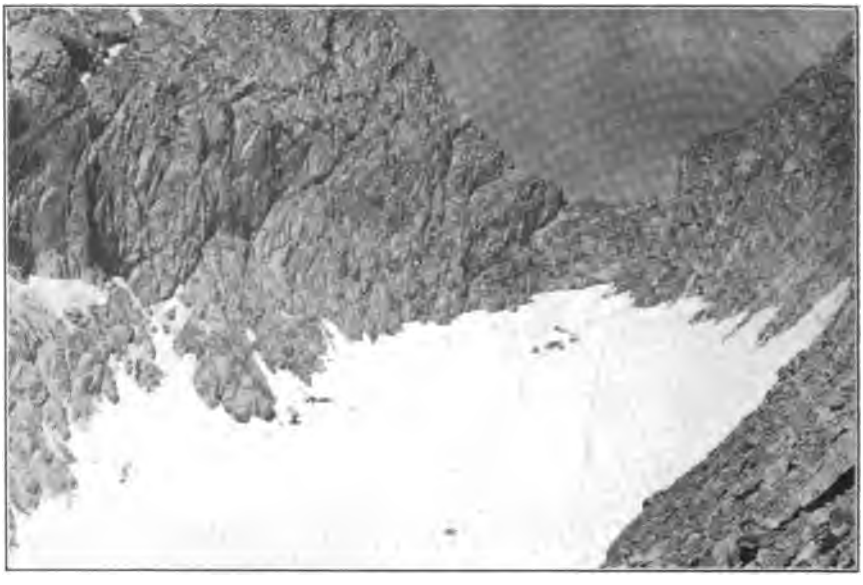
John Muir Trail. Chapter 259, Statutes 1915, appropriated $10,000 to be used toward constructing a trail in the high Sierra region, connecting Yosemite National Park with Mount Whitney and vicinity. "The trail shall be known as the 'John Muir Trail' in honor of the late John Muir, who has performed an inestimable service in making known to the world the wonders of the mountains in California."

The men of that legislature honored themselves in honoring John Muir by providing him such a monument as he would have chosen—a means of safe access to the scenes he loved so well.

The trail as located by the Department of Engineering, working in cooperative harmony with the officials of the United States Forest Service and the Sierra Club of California, begins at Mirror Lake in the

PLATE XXVIII.

The John Muir Trail—Mount Tyndall, right; Mount Whitney, right center distance; Mount Williamson, left.



John Muir Trail—Cirque at foot of Junction Peak.
(Photo, W. L. Huber.)

PLATE XXIX.

The John Muir Trail—Descent from Mount Tyndall in Shepard Pass.

The John Muir Trail—Junction Pass, from Shepard Creek.
(Photo, W. L. Huber.)

Yosemite Valley at an elevation of 4,100 feet above sea level. It then ascends the Tenaya Canyon, crossing over to the Tioga state road, follows it to Tuolumne Meadows, thence up Lyell Canyon to the main summit of the Sierras at Donahue Pass, at an elevation of 11,100 feet, thence following as near to the "Backbone" of the range as practicable, crosses or passes around the headwaters of the great streams which pour their waters into the San Joaquin Valley—the Merced, San Joaquin, Kings, Kaweah and Kern rivers, terminates at the culminating point of the Sierras, the highest point in the United States proper, the summit of Mount Whitney, at an elevation of 14,501 feet above the sea.

By cooperation with the above named agencies, much has been done in the way of constructing the John Muir Trail.

The State Engineer has personally examined the route of the proposed trail and directed its location.

The work of construction has been largely under the direction of officials of the Forest Service and acknowledgment is made of their valuable services, particular mention being made of Mr. M. A. Benedict and Mr. S. W. Wynne, forest supervisors, respectively, of Sierra and Sequoia National forests, as also of Rangers Hughes, Jordan, Slinkard and Clingan, for their intelligent direction of the work assigned to them.

The season in which effective work can be prosecuted is short, not over ten weeks, and usually the snow is not off until July. Only trained mountaineers can accomplish the work required.

It is purposed, as the trail is located and constructed, to erect permanent signs marking it so travelers may follow it without difficulty.

The Sierra Club bulletin says: "The John Muir Trail is a much greater conception than even those who first thought of its possibilities had hoped. It furnishes the great artery for high mountain travel in the Sierra and affords a wonderful opportunity for seeing this magnificent region."

While the appropriation made, augmented by funds donated by Fresno County and the Sierra Club, has enabled enough work to be done to open a passable trail from Mount Whitney to Yosemite Valley —and some of it is very excellent—a great deal remains yet to be done to improve it to a desirable condition.

It is also believed that its usefulness will be greatly enlarged if it be extended northward to Lake Tahoe.

Appropriations should be made of sufficient funds to be expended in improvement and extension as above indicated.

Naming State Roads.

In an earlier paragraph herein there was given a list of the state roads with their official names. Comment was made upon the incongruity of calling some state roads and others state highways, and the suggestion was made that inasmuch as many of these roads traverse regions which were the scenes of many historical events connected with "The days of old—the days of gold, the days of '49," they might properly bear names commemorative of those events.

In this connection it is deemed pertinent to explain that the Emigrant Gap road follows, generally, the route of the old immigrant trail, passing Donner Lake and crossing the range near where the railroad now crosses, and down to Sacramento, or Sutter's Fort, which was the objective of nearly all western-bound adventurers of those days.

Donner Lake, a most beautiful sheet of water ensconced between beetling granite crags, was made famous by the sad story of the Donner Party. This party of immigrants, caught in the winter snows on the east side of the range, were compelled to spend the winter of 1845–46 encamped on the shores of the lake, and being without provisions, 36 men, women, and children perished before rescue parties from Sutter's Fort could reach them.

What better way to commemorate that historical event than by calling the road the "Donner State Road"?

The title, "Lake Tahoe Wagon Road" is a misnomer in more ways than one. First, it does not touch Lake Tahoe at any point, but terminates at the state line, a mile from the lake shore. Second, a hundred automobiles travel over it to one *wagon*.

The greater part of this road is along the old overland stage road over which Hank Monk and other noted pioneer stage drivers piloted their mettlesome half-tamed teams, carrying gold from the mines and no less precious mail to the miners from "back home." This is a portion of the road over which the famous Pony Express was operated in 1860 and 1861, carrying mail from St. Joseph, Missouri, to San Francisco in eight days. The "postage" on letters carried in this way was one dollar.

It is suggested that "Overland State Road" would be a fitting name to apply to this road.

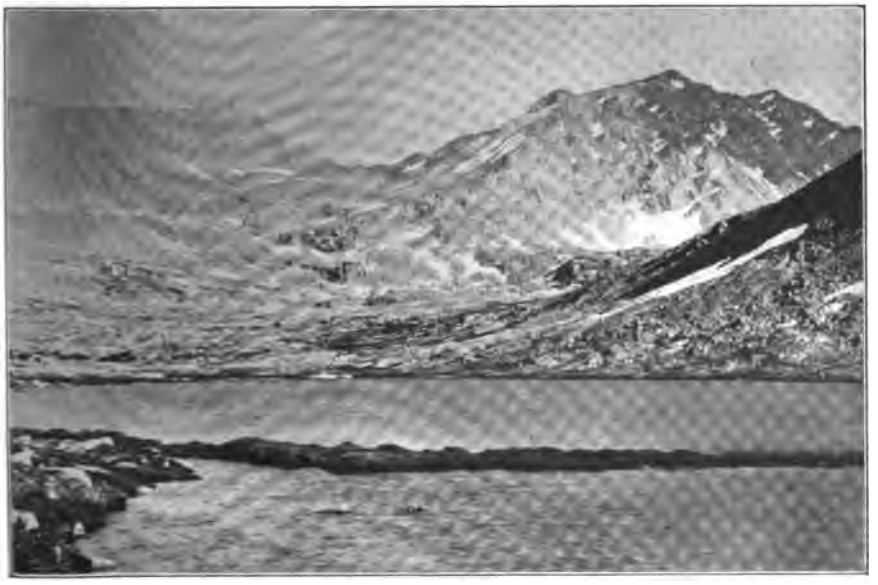
That part of the Alpine state highway from Jackson to Woodfords is strewn with reminders of the tragedies attending the efforts of the pioneers to reach the golden Mecca, over the trail blazed by Kit Carson in 1844. It was along a portion of this trail, up Carson River, through Hope Valley to the summit of the snow-covered range, that Carson guided Fremont on the memorable trip of the latter from Oregon, just before the latter seized California from the Mexican government.

PLATE XXX.

The John Muir Trail—At the head of Shepard Canyon.

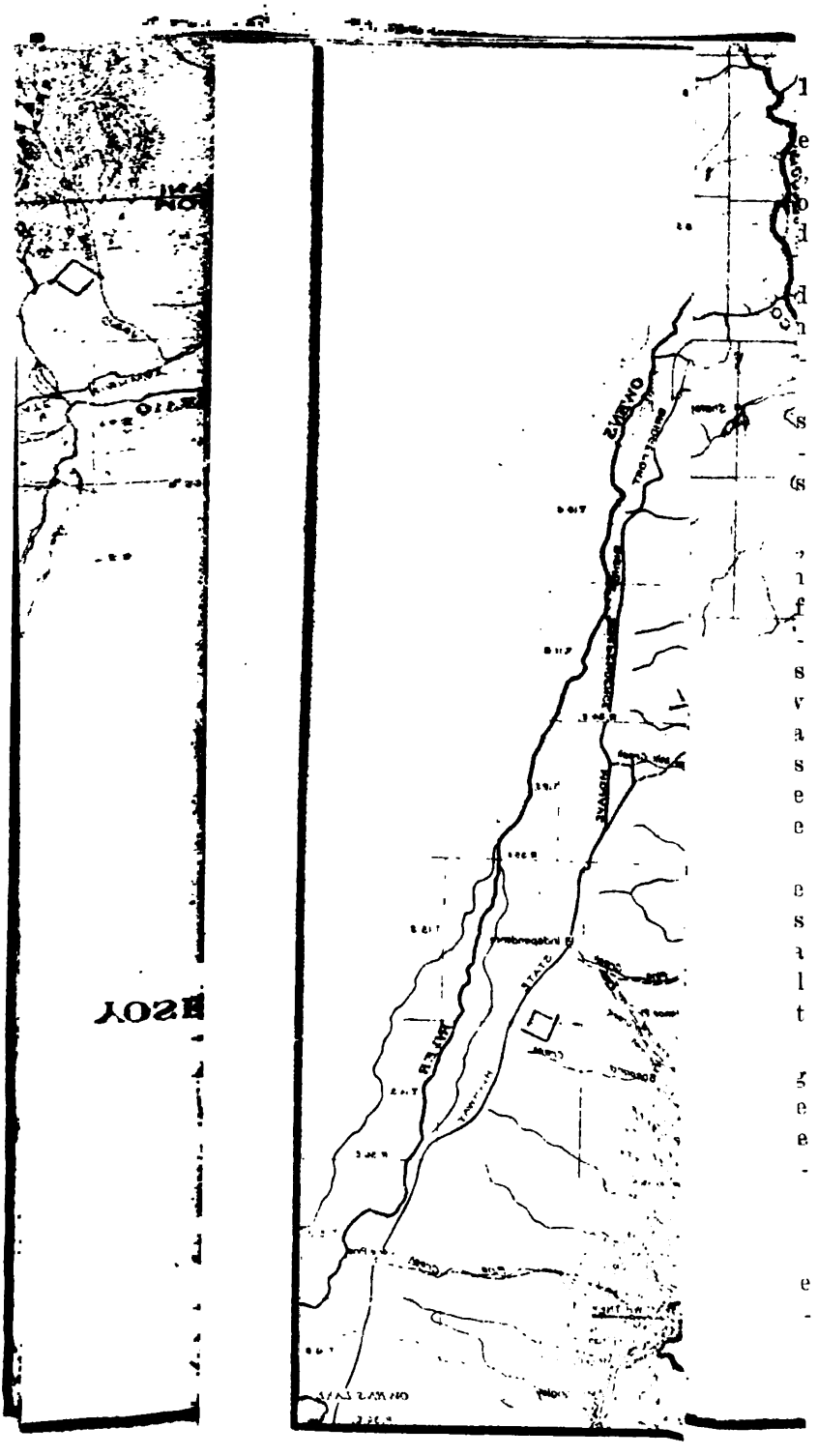
The John Muir Trail—Crossing a snowfield at head of Shepard Canyon.
(Photo, W. L. Huber.)

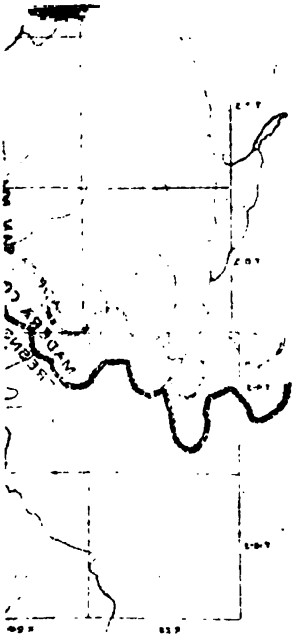
PLATE XXXI.



The John Muir Trail—From Center Basin.

The John Muir Trail—View looking west from Center Basin.
(Photo, W. L. Huber.)


OWENS
HIGHWAY
STATE
OWENS LAKE



The spot where Carson stood with Fremont on the summit on the 24th of February, 1846, was formerly marked by a sturdy pine tree, upon which the former had cut his name. This tree a few years ago was felled and the portion bearing the name carried away. The old log, badly scarred by relic hunters, still lies upon the ground.

The name "Kit Carson State Road" applied to this highway would be an appropriate memorial to the intrepid scout, guide and Indian fighter, who left his name indelibly engraved upon the pages of California's history.

And so with other roads. Each has some distinction appropriately its own and should bear a name indicative of the part it had in the history-making of the state. With appropriate names they become monuments to commemorate the early history and history-makers of the state.

But one more example will be cited here. The Big Oak Flat toll road, recently acquired as a connection with the Tioga and Mono Lake Basin roads, is distinguished for more romance than tragedy, many points of interest along it having been the scenes depicted in Bret Harte's inimitable stories of mining days. The "Luck of Roaring Camp" was enacted in the territory traversed by it. The road passes within a few yards of the hydraulic pit worked by "Tennessee and his partner" a quarter century after Tennessee had paid the penalty of his fictitious crimes at the hands of an imaginary lynching party. It is said the cabin occupied by Chaffee and Chamberlain, the originals of "Tennessee and his partner," is still standing.

At the session of the legislature in 1913 the matter of giving state roads appropriate names in conformity with the foregoing suggestions was taken up by the parlors of the Native Sons of the Golden West, a patriotic fraternal order composed of native-born Californians. A bill was introduced giving names to certain roads as above indicated, but failed to become a law.

The recommendation is now renewed that a law be enacted providing that all roads constructed from the bond issues be designated as state highways, and all other roads acquired by the state be known as state roads, and that specific names be given to certain of the latter as indicated in the foregoing discussion.

FINANCIAL STATEMENT.

The State Road Engineer submits the following statement of the expenditures made in maintenance and improvement of state roads during the last two years:

Alpine State Road—		
Roadbed construction and improvement of grade and alignment	$19,847 00	
Repairs, improvements and general maintenance	23,800 00	
Machinery, tools and equipment	3,412 00	
		$47,059 00

Auburn-Emigrant Gap State Road—		
Roadbed construction and improvement of grade and alignment	$17,050 00	
Bridges	115 00	
Culverts	119 00	
Rock retaining walls	120 00	
Machinery, tools and equipment	1,165 00	
Repairs and general improvements	2,746 00	
		21,315 00
California Redwood Park State Road—		
Construction, improvements, repairs and general maintenance	$73,582 00	
Machinery, tools, water tanks and equipment	5,210 00	
		78,792 00
Donner-McKinneys State Road—		
Roadbed construction and improvement of grade and alignment	$13,646 00	
Bridges	144 00	
Culverts	113 00	
Rock retaining walls	119 00	
Machinery, tools and equipment	2,087 00	
		16,109 00
Emigrant Gap-Donner Lake State Road—		
Roadbed construction and improvement of grade and alignment	$15,309 00	
Bridges	7,214 00	
Culverts	589 00	
Rock retaining walls	467 00	
Machinery, tools and equipment	2,863 00	
		26,442 00
Kings River State Road—		
Roadbed construction and improvement of alignment	$3,610 00	
Culverts	126 00	
Rock retaining walls	190 00	
Machinery, tools and equipment	209 00	
Repairs and general maintenance	1,823 00	
		5,958 00
Lake Tahoe State Road—		
Repairs, improvements and general maintenance	$42,524 00	
Machinery, tools and equipment	12,500 00	
Buildings	750 00	
		55,774 00
Purchase of timber land along right of way for preservation of trees, as provided by chapter 762, page 15		6,848 40
Lassen State Road—		
Repairs, improvements and general maintenance	$2,699 00	
Machinery, tools and equipment	820 00	
		3,519 00
Myers-McKinneys State Road—		
Roadbed construction and improvement of grade and alignment	$14,367 00	
Bridges	231 00	
Culverts	314 00	
Rock retaining walls	682 00	
Fencing right of way	1,938 00	
Machinery, tools and equipment	1,007 00	
Repairs, improvements and general maintenance	1,054 00	
		19,593 00

PLATE XXXII.

"Culebra Cut" on state highway, 110 feet deep.

Mono Lake Basin State Road—		
Repairs, improvements and general maintenance	$20,791 00	
Machinery, tools and equipment	550 00	
		21,341 00
Sonora-Mono State Road—		
Repairs, improvements and general maintenance	$10,305 00	
Machinery, tools and equipment	1,100 00	
		11,405 00
Tahoe City-Crystal Bay State Road—		
Roadbed construction and improvement of grade and alignment	$6,583 00	
Bridges	40 00	
Culverts	23 00	
Machinery, tools and equipment	586 00	
		7,232 00
Tioga State Road—		
Roadbed construction and improvement of grade and alignment	$15,250 00	
Bridges	1,500 00	
Culverts	2,675 00	
Rock retaining walls	1,500 00	
Machinery, tools and equipment	2,985 00	
Buildings, fences, etc.	450 00	
Surveys	1,500 00	
Purchase of right of way	3,000 00	
Repairs, improvements and general maintenance	2,425 00	
		31,285 00
Trinity-Humboldt State Road—		
Roadbed construction and improvement of alignment	$3,000 00	
Bridges	7,800 00	
Culverts	600 00	
Rock retaining walls	1,000 00	
Machinery, tools and equipment	1,450 00	
Repairs and general maintenance	8,293 00	
		22,143 00
Surprise Valley Road		20,000 00
Pescadero-Redwood Park Road		10,000 00
Yolo-Lake State Road, surveys		3,000 00
Kern-Ventura State Road, surveys		8,000 00
Pasadena State Road, surveys		7,500 00

THIRTY-THREE MILLION DOLLAR STATE HIGHWAY SYSTEM.

When $18,000,000 was voted by the people, in 1910, for the purpose of constructing a system of first-class highways throughout the state, it was well understood that the sum would be insufficient to provide all of the roads specified in the bill.

This being realized at the beginning by the builders, the policy was followed of adopting a few standard types of construction, adapted to local conditions and the traffic to be accommodated.

The types of pavement used are the following:

Base: Concrete; macadam; asphaltic concrete.
Surfacing: Asphalt; asphalt, Topeka specifications—oiled; thin bituminous.

It has been demonstrated that where a strong well-proportioned base is provided, a thin resilient covering gives comfort to the traveler, resists abrasion measurably well, is easily repaired, and when need arises can be renewed at a low cost.

The bridges constructed for the state highways are models of grace and strength. Many of them are so notable as to have received extensive commendatory notice in the technical press of the country.

When the proposition to vote $15,000,000 more with which to complete the highway system was made, the Automobile Association employed experts to examine the highways constructed, as to location, design and method of construction. The investigations were very thorough and the report approved the work unreservedly. As a consequence the association endorsed the proposed bond issue and worked for its success.

The result of the election upon the question of additional bonds being 405,000 majority in the affirmative seems to indicate that the people of the state approve of the manner in which the $18,000,000 was expended and are determined that California shall be in the vanguard of the march of twentieth century progress.

The $18,000,000 is practically all expended, and it is purposed soon to render a comprehensive account of the stewardship of this big sum. The report will be complete in detail, but as it can not be submitted in full at this time, its presentation will be deferred until the final transactions are recorded.

In the mean time a summary by the Highway Commission of its work to date is presented as follows:

STATE HIGHWAYS.

By STATE HIGHWAY COMMISSION.

The work of constructing the state highway system under the $18,000,000 bond issue has continued as heretofore under the same personnel. Three members of the advisory board of the Department of Engineering have continued as an executive committee under the designation "California Highway Commission" to have charge of the work, and the Highway Engineer of the department has acted as chief engineer and executive officer of the commission.

The $18,000,000 state highway fund is now nearly exhausted and the commissioners have in contemplation the preparation of a report of all work done thereunder, giving a complete account of their stewardship. This report will be made up at the completion of the expenditure of the state highway fund.

At the election in November, 1910, on the $18,000,000 bond issue, out of a total of 173,806 votes, there was a majority in favor of the bonds of 12,786 votes. On November 7, 1916, the voters of California considered a new bond issue of $15,000,000 for state highways. With a total of

PLATE XXXIII.

Top—State highway, Monterey County.
Middle—State Highway, San Benito County.
Bottom—State Highway, San Luis Obispo County.

(p. 194)

679,346 votes cast, there was a majority of 405,132 in favor of the highway bonds, a majority of nearly 4 to 1, and more than thirty times the favorable majority at the election of 1910. This is a showing of the increase of interest in the road problem and must in part at least be considered a vote of approval by the people of the state highways already completed under the $18,000,000 bond issue.

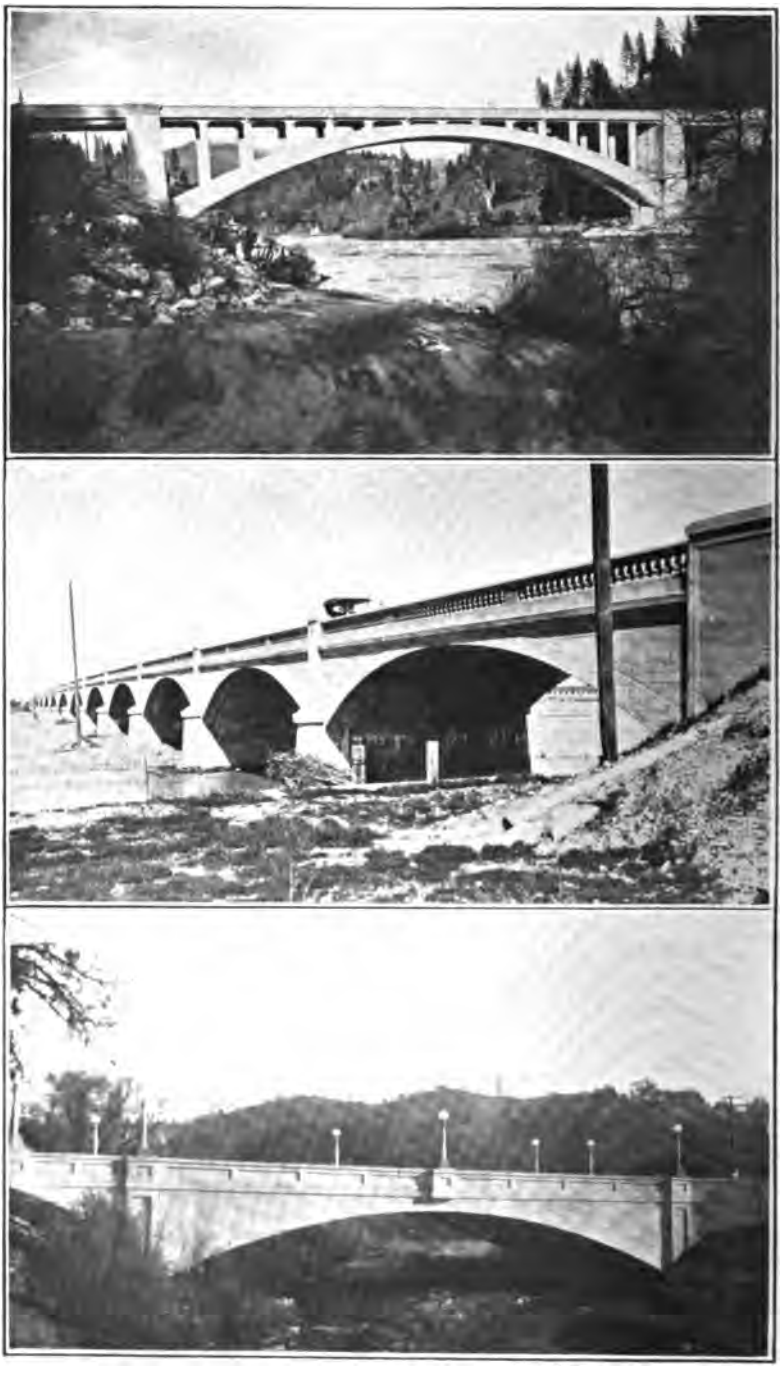
The details of the work under the first bond issue, as already stated, will be included in the final report to be made a few months from now, but a general statement of the extent of the work done during the years 1915–16 is pertinent:

Counties	Concrete		Graded only, miles
	Topeka surfacing, miles	Thin bituminous surfacing, miles	
Alameda		6.83	
Butte		12.98	
Colusa		10.60	
Contra Costa	2.55	5.37	8.47
Glenn		9.40	
Humboldt			6.98
Kings		8.95	
Los Angeles		9.11	
Marin			4.00
Monterey		39.01	
Orange		3.07	
San Benito		5.76	
San Diego		7.23	
San Luis Obispo		9.96	
Santa Barbara			11.38
Santa Clara		8.89	
Shasta			.09
Sonoma		7.01	8.12
Stanislaus		14.23	
Sutter		11.70	
Tehama		6.46	12.74
Tulare		24.08	
Yolo		3.91	
Yuba		3.28	
Totals, miles	2.55	206.78	46.73

The following table shows the mileage built from the beginning of the work to January 1, 1915:

Counties	Concrete bases			Macadam		Graded only, miles
	Asphalt surfacing, miles	Topeka surfacing, miles	Thin bituminous surfacing, miles	Topeka surfacing, miles	Oiled, miles	
Alameda			20.19	5.06		
Butte			12.68			
Calaveras						
Colusa			31.85			
Contra Costa						6.99
El Dorado			6.57		5.27	
Fresno			25.76			
Glenn			15.49			36.41
Humboldt						
Imperial			17.76			
Inyo						
Kern			61.79			10.67
Kings						
Los Angeles			41.18			27.36
Madera			16.78			9.91
Marin			.89			.88
Mariposa						
Mendocino			4.02		7.64	25.18
Merced			34.67			
Mono						
Monterey						
Napa			6.49			
Orange			38.46			6.48
Placer			9.92			
Riverside			9.34			
Sacramento			8.64			
San Benito						4.05
San Bernardino			24.62			
San Diego			42.02			
San Luis Obispo			38.74			3.61
San Mateo	5.41	5.28		5.05	.17	
Santa Barbara		6.48	20.75			13.62
Santa Clara		3.77	43.16	6.43	.08	7.59
Santa Cruz						16.05
Shasta						28.14
Siskiyou						41.55
Solano			34.08			
Sonoma			13.70			4.45
Stanislaus			21.62			1.32
Sutter						
Tehama			8.79			
Tulare						
Tuolumne						21.90
Ventura			31.55			
Yolo			18.10			
Yuba					9.22	
Totals, miles	5.41	15.53	654.61	16.54	22.38	279.16

PLATE XXXIV.



Top—Pit River Bridge.
Middle—Stoney Creek Bridge.
Bottom—Atascadero Bridge.

(p. 196)

PLATE XXXV.

Top—View on state highway in Butte County.
Middle—View on state highway in Alameda County.
Bottom—View on state highway in Marin County.

8—27335

The state highway routes in a number of counties include a considerable mileage of roads improved by county bond issues or otherwise. The following table indicates such of these improved roads as have been taken over by the Department of Engineering and made a part of the state highway system:

Counties	Concrete base, thin bituminous surfacing, miles	Oiled macadam, miles	Asphaltic concrete, miles	Graded only, miles	Bridges, miles
Sacramento	3.46	41.26			
Alameda		5.44	2.65		
Napa				8.68	
San Joaquin		33.97			
San Benito		6.95			
Santa Barbara		8.50	7.72		
Placer					.16
Humboldt					.49
Mendocino					.19
Los Angeles		39.96			
Totals, miles	3.46	136.08	10.37	8.68	.84

RECAPITULATION.

Concrete base, asphalt surfacing	6.41 miles
Concrete base, Topeka surfacing	13.08 miles
Concrete base, thin bituminous surfacing	864.85 miles
Macadam base, Topeka surfacing	16.54 miles
Macadam base, oiled	158.46 miles
Asphaltic concrete	10.37 miles
Bridges	.84 mile
Graded only	334.52 miles
Total	1,409.07 miles

In addition to the above, there are uncompleted contracts now in progress as follows:

Concrete base—thin bituminous surfacing	77.03 miles
Graded only	76.13 miles
Total mileage of roads in state highway system	1,562.23 miles

The Concrete Type of State Highway.

The commission has developed what may be called its standard type of pavement, consisting of a relatively thin concrete base covered and protected by a thin bituminous wearing coat. The concrete is laid without expansion joints and upon a well consolidated subgrade.

More than nine-tenths of the expenditure for the pavement is placed where the traffic has little chance of destroying the investment. The bulk of the road cost goes into the grading, drainage appliances and a solid concrete foundation. The wear and tear of traffic does not come in contact with this foundation as the concrete is protected by a surface coat of asphalt and mineral aggregate. Such a coat is easily applied and gives a high return in wearing qualities for its cost. This wearing coat does not roll or form ridges and hollows. It adheres firmly to the

concrete pavement, and at the end of three or four years it may be renewed by a new coat of asphaltic road oil and rock screenings.

The oldest concrete roads built by the commission have been protected by the thin bituminous wearing coat for nearly four years, and the maintenance cost has been very low.

Some Noteworthy Accomplishments.

During 1915 and 1916 the Highway Commission has completed and thrown open to traffic some constructions that have attracted considerable favorable comment in the engineering publications throughout the United States.

The Ridge route, on the route from Bakersfield to Los Angeles, has cut the mileage between these two cities by about 50 miles. This new route is so much shorter than the line of the railroad that automobile stages make the trip in less than railroad time, and allow a rest and time for lunch about midway between the cities.

In the building of this route through the mountains, nearly a million yards of material were moved on a length of 30 miles of the road.

The Yolo trestle connects the west side of the Sacramento River with the east and south, and is the only all-year-round highway crossing of the waters of the Sacramento River for a distance of 200 miles. This trestle is 3.1 miles in length, the longest concrete highway trestle in the world, and cost approximately $400,000. It was opened to traffic early in 1916.

The New Eel River bridge, south of Scotia, has been completed this month. It was designed by the engineering force of the commission. The bridge consists of two steel spans, each 302 feet 6 inches in length, six concrete spans, each 46 feet 4 inches in length, and the center pier is 100 feet high.

PLATE XXXVI.

(p. 198) Yolo Causeway, on state highway, longest concrete highway trestle in the world, 3.1 miles long.

APPENDIX A.

Expenditure on Appropriations November 1, 1914, to June 30, 1916.

Chapter	Name of job	Balance Nov. 1, 1914, and appropriations	Expended	Balance June 30, 1916
	STATE ROADS.			
Motor Vehicle	Office expenses	$19,020 48	$7,573 95	$11,446 53
Motor Vehicle	Alpine State Highway	53,886 46	33,432 00	20,454 46
Motor Vehicle	Auburn-Emigrant Gap State Highway	16,500 00	9,063 32	7,436 68
Motor Vehicle	California Redwood Park State Road	12,850 00	8,073 78	4,776 22
Motor Vehicle	Donner Lake Road	14,500 00	4,151 88	10,348 12
Motor Vehicle	Emigrant Gap Road	24,248 03	13,850 88	10,397 20
Motor Vehicle	Kings River Road	4,000 00	998 34	3,001 66
Motor Vehicle	Lake Tahoe Road	53,976 62	43,475 55	10,501 07
Motor Vehicle	Lassen State Highway	6,570 00	2,300 98	4,269 07
Motor Vehicle	Meyers-McKinneys State Highway	22,809 46	15,202 17	7,607 29
Motor Vehicle	Mono Lake Basin State Highway	21,468 58	12,272 51	9,196 07
Motor Vehicle	Sonora and Mono State Highway	7,666 99	5,431 68	2,235 31
Motor Vehicle	Trinity and Humboldt State Highway	20,741 09	18,383 61	2,357 48
Motor Vehicle	Tioga State Highway	27,650 00	16,312 15	11,337 85
468, 1911	Alpine State Highway	2 42		2 42
120, 1913	Alpine State Highway	3 89		3 89
578, 1915	Auburn-Emigrant Gap Road	10,000 00	9,531 57	468 43
398, 1913	California Redwood Park State Road	66,084 00	66,017 23	16 77
519, 1913	Emigrant Gap State Road	26 85	25 72	1 13
121, 1913	Emigrant Gap State Road	07		07
880, 1913	Emigrant Gap State Road	1,694 15	1,690 92	3 23
502, 1911	Kings River State Road	531 30	529 50	1 80
880, 1913	Kings River State Road	2,337 20	1,753 80	583 40
117, 1913	Lake Tahoe State Road — Balance	94	23 05	2 89
	Lake Tahoe State Road — Sale material	25 00		
	Lake Tahoe State Road — Total	25 94		
334, 1911	Lake Tahoe State Road	2 78		2 78
880, 1913	Lake Tahoe State Road	4,035 58	4,029 74	5 84
705, 1911	Lake Tahoe State Road	44		44
702, 1915	Lake Tahoe State Road	7,000 00	115 45	6,884 55
468, 1911	Lassen State Road	136 96		136 96
Allotted by U. S. Forest Service	Meyers-McKinneys State Road	19		19
119, 1913	Meyers-McKinneys State Road	3 89	3 89	
158, 1911	Meyers-McKinneys State Road	60		60
423, 1913	Meyers-McKinneys State Road — Balance			
	Meyers-McKinneys State Road — Credit	10 96		10 96
	Meyers-McKinneys State Road — Total	10 96		
705, 1911	Mono Lake Basin Road	1,130 16	41 10	1,089 05
880, 1913	Mono Lake Basin Road	840 97	464 82	376 15
259, 1915	Muir Trail	10,000 00	4,424 03	5,575 97
764, 1915	Pescadero and Redwood Park Road	10,000 00		10,000 00
116, 1907	Sierra and Downieville Road	86 77		86 77
705, 1911	Sonora and Mono Road	26 49	1 00	25 49
561, 1909	Sonora and Mono Road	6 73	6 73	
765, 1915	Surprise Valley State Road	20,000 00	19,764 42	235 58
680, 1915	Tahoe City to Crystal Bay Road	3,000 00		3,000 00
896, 1915	Tioga State Road	3,000 00	3,000 00	
118, 1913	Trinity and Humboldt State Road	4,949 54	4,831 29	118 25
274, 1911	Trinity and Humboldt State Road	2 93	2 93	
609, 1913	Trinity, Tehama and Shasta Roads	259 22	254 70	4 52
288, 1915	Yolo and Lake Highway	3,000 00	2,059 42	940 58
748, 1915	Bakersfield-Nordhoff Road	8,000 00	13 50	7,986 50
764, 1915	Pasadena-Antelope Valley Road	7,500 00	178 14	7,321 86
144, 1915	Colorado River bridge at Topock	*30,000 00	30,000 00	

*The Colorado River bridge was constructed by the United States Indian Service, the Department of Engineering only acting in a consulting capacity in checking, amending and approving the plans and accepting the work after completion.

APPENDIX A—Continued.

Expenditure on Appropriations November 1, 1914, to June 30, 1916.

Chapter	Name of Job	Balance Nov. 1, 1914, and appropriations	Expended	Balance June 30, 1916
	STATE ROADS—Continued.			
551, 1911	Rectifying river channels	66,583 12	66,583 12	
465, 1913	Rectifying river channels	210,990 12	141,686 95	69,303 17
697, 1915	San Rafael deep water channels (maintaining navigability)	12,500 00		12,500 00
25, 1911	Sacramento River flood control	29 86		29 86
503, 1909	Humboldt Bay survey	499 46		499 46
526, 1911	Mad River bank protection	22,790 01	15,572 60	7,217 41
14, 1901	Restraining debris	50,849 85	8,504 47	42,296 38
742, 1911	Canals and canalization of river	3 47		3 47
502, 1911	Eel River bank protection	595 68	595 18	50
	AGRICULTURAL PARK.			
443, 1913	Barns, sheds, poultry buildings	$13,986 07	$5,160 89	$8,825 18
534, 1911	Dairy buildings and barns	792 33	615 90	176 43
512, 1913	Drainage and sewage	5,331 51	1,875 19	3,456 32
532, 1911	Grandstand	64 22		64 22
201, 1915	Improvement and maintenance	5,000 00		
	Spent by Department of Engineering		415 92	
	Spent by Agricultural Society		4,584 08	
71, 1909	Machinery hall	398 68		398 68
531, 1911	Manufacturers' pavilion	602 36	38 24	584 12
533, 1911	Infield walks and improvements	189 82		189 82
221, 1915	Construction, repairs, barns, sheds	5,000 00	444 88	4,555 12
202, 1915	Women's building	30,000 00	11,512 14	18,487 86
Cont. 3	Repairs to Agricultural pavilion	735 00	731 30	3 70
	MILITIA.			
408, 1909, 362, 1911, 468, 1913	Armory, Los Angeles	$5,328 17	$2,345 72	$2,982 45
566, 1911, 469, 1913	Armory, Sacramento	2,329 59	910 14	1,419 45
379, 1909, 549, 1913	Armory, San Francisco	14,350 36	12,802 94	1,559 42
258, 1915	Naval Militia buildings, San Diego	2,500 00	2,171 49	328 51
321, 1915	Armory, Stockton	25,000 00	2,319 15	22,680 85
	SCHOOLS.			
	California Polytechnic.			
511, 1909	Barns	$24 22		$24 22
207, 1911	Dining hall	184 14		184 14
493, 1913	Heating system	10 00		10 00
270, 1911	Power, heat and light	10 21		10 21
291, 1915	Repairs to building and equipment	15,000 00	$14,989 02	69 98
548, 1911	Repairs and improvements	2 63		2 63
492, 1913	Repairs to building	146 49	2 87	143 62
271, 1911	Heating system	4 81		4 81
516, 1909	Poultry houses	05		05
102, 1913	Water system	914 91	621 45	293 46
290, 1915	Water supply	20,000 00	4,959 84	15,040 16
228, 1911	Water and sewer system	23 19		23 19
	Chico State Normal.			
173, 1913	Repairs and additions to heating system	$1,294 55	$1,215 48	$79 07
136, 1911	Passageway	25 31		25 31
224, 1915	Repairs and improvements	5,000 00	3,854 58	1,145 42
393, 1915	Grounds, swimming pool	500 00		500 00
481, 1915	Swimming pool	1,394 47		1,394 47
460, 1913	Repairs and alterations	526 68	222 68	304 00
459, 1913	Water supply	1,759 41	1,641 46	117 95
536, 1913	Street work	75 70		75 70
Cont.	Model rural school	3,500 00	3,438 65	61 35

APPENDIX A—Continued.

Expenditure on Appropriations November 1, 1914, to June 30, 1916.

Chapter	Name of job	Balance Nov. 1, 1914, and appropriations	Expended	Balance June 30, 1916
	SCHOOLS—Continued.			
	Fresno Normal School.			
207, 1915	Grounds	$9,000 00	$2,595 11	$6,404 89
584, 1911	Grounds	4,569 22	560 03	3,998 19
171, 1913	Temporary buildings	125 12	24 00	101 12
Cont.	Temporary buildings	17 94		17 94
208, 1915	Water supply	5,000 00	1,418 40	3,581 60
208, 1915	Emergency fund	2,000 00		2,000 00
516, 1913	Building and equipment	373,443 33	324,717 00	48,726 33
	Humboldt State Normal.			
204, 1915	Construction and equipment	$20,330 00	$20,240 45	$89 55
	Los Angeles State Normal.			
223, 1915	Improvement grounds	$12,000 00	$10,663 87	$1,336 13
232, 1915	Addition to manual training building	2,500 00	2,373 49	126 51
416, 1911	Building and improvement fund	56,834 84	56,822 83	12 01
428, 1913	Equipment fund	6,012 04	6,012 04	
504, 1913	Bleacher and playground equipment	196 95		196 95
303, 1911	Repairs and improvements	2,356 94	95 09	
	Spent by trustees		2,261 85	
	Preston School of Industry.			
156, 1909	Two cottages	$1,722 19	$1,140 24	$581 95
172, 1913	Cottages	20,608 22	7,608 47	12,999 75
529, 1913	Hospitals	11,991 71	808 29	11,183 42
540, 1911	Concrete floor	702 43		702 43
528, 1913 } 201, 1915 }	Repairs	42,902 92	28,027 37	14,875 55
600, 1911	Repairs	45 66	19 87	26 79
322, 1909	Pipe line	2 21		2 21
531, 1913	Addition to trades building	11,867 41	1,251 01	10,616 40
195, 1911	Water system	768 92	213 66	555 26
206, 1911	Water power plant	2,281 74	2,275 41	6 33
Cont. 3856	Club house	1,400 00		1,400 00
	San Diego State Normal School.			
226, 1915	Grounds	$5,000 00	$4,814 11	$185 89
491, 1913	Improvement grounds	65 39	62 04	3 35
584, 1913	Heating plant	13 99		13 99
284, 1915	Repairs and improvements	14,000 00	13,763 21	236 79
490, 1913	Repairs	456 24	441 19	15 05
	San Francisco State Normal School.			
128, 1911	Repairs	$23 98	$1 35	$22 63
621, 1913	Repairs and furnishing	538 48	507 43	31 05
225, 1915	Remodeling buildings	12,000 00	11,790 48	209 52
	San Jose State Normal School.			
219, 1915	Outdoor classrooms	$20,000 00	$16,643 42	$3,356 58
468, 1913	Gymnasium and playgrounds	13 22		13 22
198, 1911	Grounds	138 43		138 43
426, 1913	Repairs	185 54		185 54
243, 1915	Street improvement	20,000 00	10,329 13	9,670 87
192, 1911	Training building	07		07
	Santa Barbara State Normal School.			
225, 1915	Grounds	$6,500 00	$6,489 65	$10 35
229, 1915	Construction and equipment	15,000 00	13,890 62	1,109 38
294, 1915	Repairs	5,000 00	4,480 80	519 20
546, 1911	Main building	283 09	274 53	8 56
547, 1911	Lunch room	4 89	1 16	3 73

APPENDIX A—Continued.

Expenditure on Appropriations November 1, 1914, to June 30, 1916.

Chapter	Name of job	Balance Nov. 1, 1914, and appropriations	Expended	Balance June 30, 1916
	SCHOOLS—Continued.			
	Ventura State Training School for Girls.			
239, 1915	Commissary building	$7,000 00	$5,567 48	$1,432 52
318, 1915	Cottages	52,500 00	47,311 09	5,188 91
241, 1915	Cottage for males	6,100 00	5,035 78	1,064 22
262, 1915	Drains	7,500 00	7,363 75	136 25
240, 1915	Farm buildings	6,000 00	4,263 84	1,736 16
319, 1915	Garage	2,500 00	1,871 68	628 32
320, 1915	Grounds	7,500 00	5,482 36	2,017 64
401, 1913	Construction and equipment	170,755 72	166,736 54	4,019 15
Cont. 2604	Water system	500 00		500 00
	Whittier State School.			
238, 1915	Cottages	$60,000 00	$1,695 01	$58,304 99
166, 1911	Cottage	9,964 69	8,427 70	1,536 99
233, 1911	Dairy barn	94 98	81 78	13 20
169, 1911	Electric light plant	3,000 00		3,000 00
194, 1909	Manual training building	920 98	920 98	
427, 1913	General repairs	2,015 94	1,353 51	662 43
232, 1911	Repiping	771 72	770 49	1 23
317, 1915	Repairs and improvements	20,000 00	18,604 40	1,395 60
Cont.	General repairs	5,000 00	4,989 80	10 20
Cont. 1408	Water system	1,000 00	541 45	458 55
	California School for the Deaf and Blind, Berkeley.			
442, 1913	Dairy barn	$3,149 24	$2,839 41	$309 83
249, 1915	Fire escapes	1,500 00	1,459 67	40 33
248, 1915	Electric wiring	12,500 00	1,832 73	10,667 27
440, 1913	Gymnasium	48,314 40	46,952 71	1,361 69
277, 1915	Heating system	25,000 00	551 68	24,448 32
665, 1911	Manual arts building	12,191 23	58 41	
	By trustees		11,744 02	
			11,797 43	393 80
514, 1913	Repairs and improvements	340 43	144 22	196 21
247, 1915	Repairs and improvements	8,550 00	7,410 25	1,139 75
251, 1915	Repairs and improvements	4,500 00	4,003 74	496 26
250, 1915	Wells and equipment	4,000 00	20 00	3,980 00
569, 1909	Improvements	2 64		2 64
523, 1911	Water supply	8 80		8 80
441, 1913	Machinery and equipment	2,350 00	2,311 42	38 58
	Industrial Home of Mechanical Trades for Adult Blind, Oakland.			
418, 1913	Dormitory	$31,059 55	$30,088 05	$971 50
419, 1913	Floors	102 68		102 68
245, 1915	Repairs and improvements	4,000 00	3,091 97	908 03
	HOMES.			
	Sonoma State Home.			
208, 1915	Barracks	$10,000 00	$1,477 07	$8,522 93
506, 1913	Cottage for epileptics	16,361 75	16,314 97	46 78
435, 1913	Dormitory	4,779 98	3,786 80	
	Expended by trustees		984 84	58 34
509, 1913	Building for farm hands	225 30		225 30
209, 1915	Grounds and roads	5,000 00	2,714 02	1,430 23
	By trustees		855 75	
436, 1913	Nursery for males, balance	4,107 99		
	Furnishing	1,500 00		
	Net	$2,607 99	2,474 76	133 23
296, 1915	Nursery for girls, appropriation	$25,000 00		
	Furnishing	3,000 00		
	Net	$22,000 00	1,920 59	20,079 41

APPENDIX A—Continued.

Expenditure on Appropriations November 1, 1914, to June 30, 1916.

Chapter	Name of job	Balance Nov. 1, 1914, and appropriations	Expended	Balance June 30, 1916
	HOMES—Continued.			
	Sonoma State Home—Continued.			
568, 1909	Power house and boilers	$52 66		$52 66
519, 1911	Reflooring	723 34	$163 46	559 88
448, 1909	Manor house	18 78		18 78
434, 1913	Septic tanks	1,973 76	1,972 67	1 09
239, 1911	Water supply	27 60		27 60
433, 1913	Water supply	9,278 41	4,171 36	5,107 05
297, 1915	Repairs and repiping	16,750 00	501 89	16,248 11
Cont. 647	Cannery building	1,295 59	997 57	298 02
Cont. 1121, 1122	Tubercular hospital	3,429 36	70 72	3,358 64
Cont. 1124	Plans for grounds	250 00	52 48	197 52
Cont. 1668	Concrete conduit	2,391 82	2,298 92	92 90
Cont. 778	Water purifier and storage tank	475 04		475 04
Cont. 1287	Electrical apparatus	7 68		7 68
Cont. 1264	Boiler for power house	179 83	1 92	177 91
Cont. 1718	Oil tank	850 00		850 00
	Veterans' Home.			
488, 1913	Amusement, assembly and library bldg.	$14,970 24	$14,785 52	$184 72
214, 1915	Bath rooms in barracks	15,000 00	4,578 08	10,421 92
235, 1911	Cold storage	31 71		31 71
511, 1911	Cottage C	1,792 10	1,693 85	98 25
212, 1915	Cottages	22,500 00	1,165 92	21,334 08
484, 1913	Dairy and cow barns	309 99	269 00	40 99
252, 1909	Water distilling plant	79 82		79 82
216, 1915	Electric wiring	3,500 00	15 12	3,484 88
236, 1911	Fire escapes	255 63		255 63
508, 1911	Grounds and appurtenances	123 82	20 91	102 91
489, 1909	Addition to hospital	67 20	66 30	90
409, 1913	Lavatories	24 65		24 65
410, 1913	Painting	4,350 99	4,314 66	36 33
470, 1913	Pipe line	977 51	580 08	397 43
482, 1913	Repairs to plumbing	4,973 80	3,981 29	992 51
507, 1911	Plumbing	1,000 00	217 11	782 89
215, 1915	Plumbing repairs	10,000 00	1,860 99	8,139 01
508, 1909	Repairs to buildings—			
	Balance $6 72			
	Credits 21 75			
		28 47	18 88	9 59
411, 1913	Repairs to buildings	1,891 84	1,815 09	76 75
509, 1911	Repairs to buildings	967 99	767 17	82
488, 1909	Storehouse and commissary	172 09	63 89	108 20
521, 1911	Septic tanks	1,122 65	247 31	875 34
510, 1911	Surgeon's residence	66 07		66 07
	Maintenance Fund—Installing irrigation and oil pipes	2,500 00	1,759 90	740 10
213, 1915	Repairs	15,000 00	4,441 97	10,558 03
	General Fund to complete surgeon's residence	223 35		223 35
	General Fund—Addition to dining room	189 40		189 40
	General Fund—Addition to power house	152 68		152 68
	General Fund—Cold storage	141 32		141 32
	HOSPITALS.			
	Agnews State Hospital.			
528, 1911	Reconstruction	$1,115 77	$300 45	$815 32
400, 1913	Workers' cottage	41,464 87	34,942 94	6,521 93
472, 1913	Nurses' home	42,700 59	40,402 85	2,297 74
606, 1913	Wiring conduits and repairing steam lines	2,036 73	1,998 39	38 34
754, 1915	Construction and furnishing of patients' cottage or cottages	22,500 00	229 48	22,270 52
Cont. est. 546	Miscellaneous repairs	6 95		6 95

APPENDIX A—Continued.

Expenditure on Appropriations November 1, 1914, to June 30, 1916.

Chapter	Name of job	Balance Nov. 1, 1914, and appropriations	Expended	Balance June 30, 1916
	HOSPITALS—Continued.			
	Agnews State Hospital—Continued.			
Cont. est. 727, 1914	Installing one 250 horsepower boiler	$45 27		$45 27
Cont. est. 706, 945, 1913	Imp. of heating system and cooperage	8 57		8 57
Cont. est. 688, 761, 1208, 1913	Gas holder	158 89	$99 25	59 64
Cont. 946, 1913	Repairs to fan heating system	29 63	13 63	16 00
Cont. 82, 199, 1914	Temporary barracks	32,253 03	31,979 53	273 50
Cont. est. 92	Completion of electric system	1,056 00	1,047 80	8 20
Cont. est. 378, 1915	Changing and refitting old plumbing fixtures and buying and installing necessary new fixtures	1,900 00	1,791 99	108 01
Cont. est. 434, 1915	Completion of steam heating system	2,305 18	1,727 08	578 10
Cont. est. 689, 905, 402, 2332, 1915	For furnishing and installing a clock system as per specifications and bid	7,660 00	21 30	7,637 70
481, 1913	Gas plant	5,498 60	5,494 70	3 90
107, 1913, 149, 1911	Dam and reservoir	6,050 40	3,007 49	3,042 91
125, 1911	Male cottage	261 82	3 60	258 22
220, 1915	Purchase and installation of three electric elevators	7,500 00	97 56	7,402 44
192, 1915	Replacement of a main pipe line and connections thereto and completion of the reservoir and water systems	15,000 00	5,764 29	9,235 71
305, 1915	Plumbing repairs	5,000 00	230 81	4,769 19
Cont. 379,	Assistant physician's residence	398 14		398 14
Cont. 444,	Salary of B. B. Kinkade	75 38		75 38
Cont. 553,	Survey of grounds	35 87		35 87
Cont. 413, 1915	For labor and material for repairs and reinforcement of middle dam of hospital water supply system for irrigation and domestic use	$1,500 00	$927 44	$572 56
669, 960, 1915	For labor and materials for alterations and construction of kitchen and service buildings	14,131 00	6,041 54	8,089 46
670, 1915	Steward's residence	3,000 00	2,424 11	575 89
216, 1914	Labor of J. C. Warren on gas plant	75 00	75 00	
108, 1914	Completion of gas plant	549 01	534 07	14 94
984, 1916	Survey of plumbing, water and steam system	250 00	126 01	123 99
965, 1915	Construction of two gas pipe lines, heaters, services and ranges in the officers' quarters	1,600 00	141 14	1,458 86
986, 1916	Construction of a concrete conduit through the proposed service building	650 00	111 73	538 27
891, 1052, 1916	Cottage for manager and guests	4,500 00	1,998 46	2,501 54
1053, 1916	Inspection of work	1,000 00	458 00	545 00
1058, 1916	Installation of substation equipment, transmission lines, distributing lines and lighting system	8,500 00	480 54	8,019 46
2607, 1916	Remodeling of second floor of administration building	3,000 00	11 75	2,988 25
316, 1909	Water system	26		26
406, 1913	Steam boilers	708 85	708 56	29
407, 1913	Cottages (Dozier and Chambers)	13,267 81	10,893 46	2,374 35
560, 1911	Cold storage plant	49 99		49 99
487, 1913	Dairy buildings	13,326 92	12,908 46	1,018 46
486, 1913	Dormitories and sheds	5,922 52	5,488 80	433 72
489, 1909	Female cottage	319 48		319 48

APPENDIX A—Continued.

Expenditure on Appropriations November 1, 1914, to June 30, 1916.

Chapter	Name of Job	Balance Nov. 1, 1914, and appropriations	Expended	Balance June 30, 1916
	HOSPITALS—Continued.			
	Agnews State Hospital—Continued.			
408, 1913	Steam heating system	$1,321 48	$1,173 09	$148 39
505, 1911	Irrigation	541 99	537 45	4 54
314, 1909	Kitchen	51 99		51 99
405, 1913	Laundry	6,712 66	6,457 67	254 99
404, 1913	North pay cottage	1,198 05	1,946 10	46 95
315, 1909	Receiving and treatment building	34 88		34 88
489, 1913	Reclamation of lowlands	3,959 11	3,178 95	780 16
488, 1913	Rewiring	1,606 74	980 06	73 72
327, 1915	Remodeling south pay cottage	15,000 00	3,927 24	11,072 76
325, 1915	Men patients' cottage	15,000 00	465 96	14,534 04
352, 1915	Repairs and equipment of power house	5,000 00	538 35	4,461 65
324, 1915	Women patients' cottage	15,000 00	1,611 83	13,388 17
326, 1915	Home for working men	15,000 00	800 79	14,199 21
Cont. 765, 805, 1912	Transformers	726 88		726 88
709, 1913	Addition to south pay cottage	3 49		3 49
339	Plumbing—Ward No. 3	67 52		67 52
945, 980, 1045, 1100	Two parole cottages	$172 69		$172 69
504, 722	Laying out of grounds	28 31		28 31
913	Cold storage plant	9 24		9 24
1468, 51, 135	Amusement hall	1,736 40	$1,703 20	32 20
1197	Telephone system	17 26	11 63	5 63
Contingents:				
1329	Light and power system	4 79	4 75	04
1429	Power line	18 37	18 35	02
1618	Pipe covering	2 36		2 36
1629	Alteration of 4 hot water storage tanks	88 05	82 39	66
1683	Heating system	9,609 39	9,606 17	3 22
171, 1914	To finish reclamation of lowlands	1,000 00	694 05	305 95
298, 1914	Repairs to floors	900 00	558 07	*341 96
464, 887, 1915	Remodel bakery and kitchen	6,500 00	5,920 11	579 89
686, 1915	Bungalow for Dr. G. W. Ogden	2,500 00	1,836 45	663 55
788, 2687, 1269, 1915	Replacing roof covering of laundry and making survey of sewer pipe	775 00		775 00
1027, 1915	Drafting and inspection	100 00	75 47	24 53
1449, 1028, 1268, 1916	Tower	2,350 00	35 95	2,314 05
1267, 1916	Alterations of assembly building and construction of classrooms	4,700 00		4,700 00
2214, 1916	Power plant equipment	346 89		346 89
2928, 1916	Cost of bringing sewer line and heating conduit to cottages for men and women patients	850 00		850 00
455, 1913	Site and buildings	159,372 93	158,393 12	979 81
237, 1915	Support and maintenance and erection of additional buildings	195,000 00		
	Support	105,000 00	46,456 05	43,543 95
		$90,000 00		
	Southern California State Hospital.			
461, 1909	Assistant physician's residence	$2 16		$2 16
477, 1913	Four cottages	1,130 98	$359 13	771 85
462, 1909	Dining hall	244 27		244 27
215, 1911	Female cottage	1 85		1 85
457, 1909	Cottage No. 2, females	17 00		17 00
459, 1909	Cottage for females	50 90		50 90
185, 1907	Dairy barns	185 10		185 10
496, 1913	Laundry	16,630 48	16,621 97	8 51
466, 1909	Receiving cottages	65 64		65 64
231, 1911	Power plant	3,887 55	3,779 85	107 70

*Returned to Contingent Fund.

APPENDIX A—Continued.

Expenditure on Appropriations November 1, 1914, to June 30, 1916.

Chapter	Name of job	Balance Nov. 1. 1914, and appropriations	Expended	Balance June 30. 1916
	HOSPITALS—Continued.			
	Southern California State Hospital—Continued.			
497, 1913	Reservoir—			
	Balance $206 34			
	Credit 5 20			
		$211 54	$2 66	$208 88
458, 1909	Storm drains	274 71	.....	274 71
		50,000 00	.....	.....
218, 1915	Construction and furnishing 2 cottages..	8,500 00	.....	.....
		$41,500 00	39,748 98	1,751 02
307, 1915	Water supply	10,000 00	2,223 16	7,776 84
Contingents:				
375, 890	Wiring	4 79	.....	4 79
311	Cottages for physicians.....	10 80	.....	10 80
454, 957, 1009	Porch for Cottage E.....	92 25	.....	92 25
455	Porch for Cottage F.....	103 94	.....	103 94
456	Cottage I	492 68	.....	492 68
731, 960, 1079	Heating system	9,059 55	8,652 88	406 67
871	Heating system	469 78	.....	469 78
66	Cover for reservoir.....	19 15	.....	19 15
40, 408, 616	Superintendent's residence	11,398 47	11,304 75	93 72
1096, 1916	New chicken yards and equipment.....	3,500 00	45 58	3,454 42
		.....	39 20	.....
3304, 1916	Repairing walls of west wing main bldg.	1,500 00	*1,460 80	.....
499, 1913	Dairy building	†17,145 52	‡1,200 00	.....
		.....	504 87	.....
		.....	15,440 65	.....
414, 1913	Elevators	3,089 93	3,003 84	86 09
127, 1911	Fire protection system.....	465 35	72 66	392 69
415, 1913	Heating system	424 32	144 59	279 73
197, 1911	Heating system	210 41	18 47	191 94
126, 1911	Sewing room and dormitory.....	261 48	.....	261 48
243, 1909	Telephone system	1 04	.....	1 04
		.....	2,523 47	.....
416, 1913	Ward No. 25.....	22,119 48	19,169 79	426 22
129, 1911	Water system	1,006 98	321 93 $685 05	.....
211, 1915	Boiler	7,000 00	5,917 20	1,082 80
		30,000 00	.....	.....
	Furnishing	3,000 00	.....	.....
210, 1915	Females, convalescent building.....	$27,000 00	4,345 50	22,654 50
		30,000 00	.....	.....
	Furnishing	3,000 00	.....	.....
310, 1915	Cottage for males.....	$27,000 00	4,113 95	22,886 05
309, 1915	Electric wiring	$10,500 00	$9,829 30	$670 70
300, 1915	Farm buildings	7,000 00	5,173 79	1,826 21
		8,000 00	.....	.....
	Furnishing	1,000 00	.....	.....
350, 1915	Two physicians' cottages.....	$7,000 00	291 95	6,708 05
Contingents:				
1516	Completion of fire protection system....	54 57	.....	54 57
410	Plumbing	11 90	.....	11 90
612	Plumbing	12 99	.....	12 99
770, 793	Plumbing	87 76	.....	87 76
854	Inspection of generating plant.....	13 58	.....	13 58
867, 2150, 1915,	Hot water heater.....	707 82	704 09	3 73
261, 1914	Completion of elevators.....	281 00	22 75	258 25

*Returned to Contingent Fund.
†Equipment.
‡Returned to institution.
§By trustees.

APPENDIX A—Continued.

Expenditure on Appropriations November 1, 1914, to June 30, 1916.

Chapter	Name of job	Balance Nov. 1, 1914, and appropriations	Expended	Balance June 30, 1916
	HOSPITALS—Continued.			
	Southern California State Hospital—Continued.			
184, 1905, 449, 1913	Cells and walls	$95,162 75	$89,860 73	$5,301 97
447, 1913	Construction of dairy and farm building	2,515 83	1,783 22	732 61
573, 1909	Additional houses	1,347 75		1,347 75
558, 1909	Boilers	51 35		51 35
450, 1913	Laundry and equipment	9,841 26	9,190 46	650 80
448, 1913	Repairs	10,686 89	10,448 20	238 69
			36 16	
451, 1913	Shop buildings and equipment	32,422 83	*32,386 67	
562, 1909	Warden's residence	3,909 92	3,671 14	238 78
199, 1915	Cells and walls and other improvements	32,386 67	30,843 23	1,543 44
273, 1915	Cells and other improvements	37,605 08	21,102 76	16,502 32
313, 1915	New bake oven	5,000 00		5,000 00
311, 1915	Farm buildings	1,500 00	1,372 25	127 75
312, 1915	Refrigerating plant	6,000 00	1,906 15	4,093 85
315, 1915	Power house, reconstruction and equipment	31,000 00	21,431 06	9,568 94
316, 1915	Repairs and improvements	20,000 00	9,877 46	10,122 54
314, 1913	Warden's residence (to be spent by prison directors)	4,000 00		
	PRISONS.			
	San Quentin State Prison.			
562, 1911	Cells and walls	$71,244 93	$56,393 91	$14,851 02
579, 1909	Guards' cottages	2,953 78	2,639 99	313 79
		32,000 00		
	Set aside for directors	21,000 00		
322, 1915	Repairs and improvements	$11,000 00	4,057 15	6,942 85
228, 1915	Water supply and pumping plant	5,000 00	523 63	4,476 37
	MISCELLANEOUS.			
	Owens River fish hatchery	$38,978 00	$11,812 80	$27,165 20
541, 1913	San Francisco State Building Fund	1,000,000 00	112 04	999,887 96
223, 1915; est. No. 2320	Los Angeles expo. bldg., stairways	3,150 00	169 88	2,980 62
		3,000 00		
	Expended by treasurer	1,500 00		
263, 1915	State Treasurer's office, equipment, etc.	1,500 00	976 47	523 53
532, 1913	State Capitol grounds, conservatory	199 17	153 44	45 73
538, 1913	Elevators, State Capitol building	2,662 95	2,623 10	39 85
	State Library Fund, elevator	7,282 49	7,228 26	54 23
			*3,468 64	
193, 1915	Governor's residence	5,000 00	655 76	875 60
603, 1913	State Capitol building, painting	5,733 23	5,634 23	99 00
565, 1911	Filing cases	2 57		2 57
322, 1911	Mission Solano, Sonoma, restoring	109 84		109 84
480, 1913	Mission Solano, Sonoma, repairs	982 19	29 83	952 36
603, 1915	Mission Solano, Sonoma, curb and gutter	300 00	195 88	104 12
272, 1915	State printing plant, painting	2,000 00	1,997 44	2 56
679, 1915	Greek chapel at Fort Ross, restoration and rebuilding	2,000 00		2,000 00
705, 1911 40, 1913 680, 1913	Contingent expense, Dept. Eng.	9,012 44	8,963 96	48 48
288, 1915	Contingent expense, Dept. Eng.	17,500 00	15,528 94	1,971 02
705, 1911	Contingent expense, Dept. printing	955 67		955 67
680, 1913	Contingent expense, Dept. printing	2,915 07	1,839 56	1,075 51
288, 1915	Contingent expense, Dept. printing	2,500 00	275 42	2,224 58

*Reappropriated.

APPENDIX A—Continued.

Expenditure on Appropriations November 1, 1914, to June 30, 1916.

Chapter	Name of job	Balance Nov. 1, 1914, and appropriations	Expended	Balance June 30, 1916
	MISCELLANEOUS—Continued.			
398, 1915	Emergency fund, drafting	$16,000 00 *12,000 00 *612 90	$864 68	$15,635 32
	Three architectural draftsmen	$11,367 10	5,367 10	6,000 00
398, 1915	General appropriation	4,200 00 *214 50		
	One testing engineer	$3,985 50	1,885 50	2,100 00
398, 1915	General appropriation	5,400 00 *275 80		
	One mechanical engineer	$5,124 20	2,424 19	2,700 01
398, 1915	General appropriation	7,200 00 *367 70		
	Two filing clerks	$6,632 30	3,232 26	3,400 04
398, 1915	General appropriation	3,000 00 *153 20		
	Blue-print pressman	$2,346 80	1,346 77	1,500 03
398, 1915	General appropriation	6,000 00 *306 40		
	Two clerks and stenographers	$5,698 60	2,698 54	3,000 06
398, 1915	General appropriation	1,800 00 *91 95		
	One porter and messenger	$1,708 05	808 05	900 00
	COOPERATIVE RESEARCH.			
704, 1909	Topographic survey—			
	Appropriated July 1, 1915	$14,000 00	$10,118 01	$3,881 99
	Appropriated July 1, 1916	14,000 00	13,867 94	132 06
704, 1909	Hydrographic survey—			
	Appropriated July 1, 1915	9,000 00	8,999 97	03
	Appropriated July 1, 1916	9,000 00	8,170 22	829 78
704, 1909	Irrigation (Adams) survey—			
	Appropriated July 1, 1915	7,000 00	6,995 60	4 40
	Appropriated July 1, 1916	7,000 00	6,725 46	274 54
		$60,000 00	$54,877 20	$5,122 80

*Paid direct.

STATE OF CALIFORNIA
DEPARTMENT OF ENGINEERING

APPENDIX B

Being a Reprint of Bulletin No. 2, issued
by the Department of Engineering, 1916

Irrigation Districts in California

1887-1915

By FRANK ADAMS, Irrigation Manager
Office of Public Roads and Rural Engineering
United States Department of Agriculture

(Based on data gathered under cooperative agreement between the Office of Public Roads and Rural Engineering of the United States Department of Agriculture and the California State Department of Engineering.)

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PREFACE.

Irrigation Districts in California, 1887–1915, a historical sketch of the operations of the Wright Irrigation District law with descriptions of the 49 districts formed under that law, their successes and failures, together with an account of the amendment of the Wright law in 1897 and subsequently, and of operations under the amended law, compiled by Frank Adams, was published as Bulletin No. 2 by the State Department of Engineering early in 1916. The demand for the book was so great that the edition was exhausted in a very short time, and in order to satisfy several hundred requests for it the matter is here reproduced as an appendix to the biennial report of the department.

In order to fully understand why so few of the districts were not successful it is only necessary to carefully read their individual histories as set forth herein, when it will be seen that many of the failures were not due to inherent defects of the law.

The list of court cases affecting irrigation districts appearing in Addendum III, page 133, will be found useful to the student of irrigation law, and Addendum IV, giving an outline of the present irrigation district law, will answer many questions occurring to the proponents of new districts.

A careful perusal of the entire document is commended to all who are interested in the promotion of irrigation under any district or cooperative plan.

The text of this history was completed in 1915, and gives conditions as they existed at that time. The entire text is preserved as published in Bulletin No. 2, but where important conditions are known to have changed, or new districts organized, mention of which does not appear in the text, the omissions will be found supplied in appropriate foot notes.

An exception to this rule is the map of California appearing opposite page 60, and showing the location of all existing districts, which is brought up to date as of November 30, 1916.

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IRRIGATION DISTRICTS IN CALIFORNIA, 1887-1915.

INTRODUCTION.

The irrigation district is now an established institution in California. First authorized in California on a comprehensive basis in 1887, after an agitation in favor of neighborhood irrigation extending over at least fifteen years, and with extreme bitterness toward riparian proprietors, following the decision in *Lux* vs. *Haggin,* probably furnishing much of the motive force that carried the Wright act of 1887 through the legislature, it has been found to be a workable and desirable plan for community ownership and operation of irrigation works. It is not the form of irrigation organization that is numerically strongest in California, nor is it very likely to attain numerical precedence over the cooperative or mutual irrigation company. Neither is it the form of organization under which the largest acreage is now irrigated in this state. It is, however, the form of organization that is now most generally considered both for new and for the reorganization of old irrigation development in California, as it is the form that has been most largely employed in this state in the more important new irrigation development and reorganization of the present decade.[1]

The irrigation district idea did not originate in California. Prior to the passage of the Wright act, Italy, France, and Spain had provided for neighborhood irrigation systems to which the district plan is somewhat similar. Municipal organization had also been employed in drainage. The first irrigation district legislation in the United States was passed by Utah in 1865. That legislation provided that county clerks, on application of a majority of landowners in areas proposed to be organized, should create districts. In those districts landowners were the electors, if land taxes were to be levied, or taxpayers, if general property taxes. A few districts were formed under that act, but

[1]This report deals only with irrigation districts organized under the original Wright act of 1887 and the act of 1897 as amended to 1915. Three additional district acts were passed in 1913, but these were drawn to meet special situations and should not be confused with the general California irrigation district act. These special acts were as follows: Statutes 1913, chapter 370, providing for the organization of county irrigation districts (changed by Statutes 1915, chapter 39, to county waterworks districts) and intended to facilitate water distribution for irrigation purposes from the Los Angeles aqueduct; Statutes 1913, chapter 387, providing for the organization of water districts and intended to facilitate organization of a large desert area along the Colorado River in Chuckawalla Valley; and Statutes 1913, chapter 592, providing for the organization of county water districts. Several districts have been organized under the first of these acts but there has been no organization under the other two. Statutes 1915, chapter 621, known as the "California Irrigation Act," another act designed to meet a particular situation, authorizes irrigation districts to reorganize under it, but no such reorganization is now contemplated by existing districts.

nothing important was accomplished. The first California irrigation district act was passed in 1872, "An act to promote irrigation by the formation of irrigation districts." It provided that owners of lands desiring to irrigate or drain them might petition the county supervisors for the formation of irrigation districts. It was required, in the case of any proposed district, that the petition should contain a description of the land, the names of the landowners, and the names of three persons whom it was desired should serve as trustees for the first three months. After verification and publication of the petition the supervisors were required to grant it. By-laws, powers of trustees, reports, and assessments were briefly provided for. The law was inoperative. In 1874 an act was passed, applicable only in Los Angeles County, providing for the office of county superintendent of irrigation, whose duty it should become, upon petition of a majority of the property owners in any given area, to examine the plans and the feasibility of any irrigation system proposed therefor, and thereupon to notify the county supervisors, who should then call an election upon the question of taxation for the construction of irrigation works, and the election of water commissioners, only taxpayers being permitted to vote in any such election. There was no organization under that act. In 1876 another special act was passed creating the Westside Irrigation District. That law provided for five commissioners, an assessor, a collector, and a treasurer. It further provided for issuing 20-year 8 per cent bonds to the amount of $4,000,000.00, to be redeemed by direct tax levy, and to be a lien upon the lands within the district. Surveys were made for a canal from Tulare Lake to Antioch, but all effort under the act soon lapsed. A final special act, creating Modesto Irrigation District, covering the area now generally embraced in Modesto and Turlock districts, was passed in 1878. That act provided that direct taxes should be levied only for repairs and that the construction fund should ultimately be secured from the increase in the gross tax receipts expected to follow a contemplated rise in land values. The credit of the state and of Stanislaus County was pledged for the payment of bonds up to $500,000.00. As in the case of previous special acts, nothing substantial resulted from that one.

The period of the seventies and eighties in California was one of intense interest in and of great controversy over irrigation. The spirit of development was widespread, but large landowners and riparian proprietors seemed generally to be arrayed against agitation for community endeavor. When the office of state engineer was created in 1878, one of the chief duties of the state engineer was the study of irrigation, and in his first important report, presented in 1880, he out-

lined an act governing the formation of irrigation districts. For the first few years following, efforts in behalf of irrigation legislation seem mainly to have been directed toward the enactment of a general irrigation law for the state, and against riparian owners. In 1886, however, Mr. C. C. Wright, a lawyer of Modesto, who for some years had been carefully studying irrigation and who was familiar with progress in Europe and elsewhere, and who, also, represented a typical San Joaquin Valley community striving to obtain an irrigation water supply and to construct a community irrigation system in spite of opposing large landowners, was sent to the legislature expressly, it has been said, to procure the passage of a law under which such communities as his own could build and operate their irrigation works. For ten years progressive farmers in Stanislaus County had been advocating the construction of an irrigation system to permit of substituting irrigation farming for the grain farming that had already begun to be unprofitable. They had not, however, been able to agree on any plan. The only hope seemed to lie in a law under which the opposing minority could be forced into compliance with the will of the majority, and to pay their just proportion of the cost. The decision in *Lux* vs. *Haggin* had just been rendered and advocates of irrigation by appropriation were ready to join enthusiastically in any measure that promised relief.

The irrigation district act passed by the legislature of 1887, known as the "Wright Act," remained on the statute books for ten years, with important amendments, drafted in the light of experience, adopted in 1889, 1891, 1893, and 1895. In 1897 it was rewritten, considerably enlarged, and re-enacted as an entirely new act, variously known as the "Bridgford Act," the "Irrigation Act of 1897," and the "California Irrigation District Act." Many further amendments have been made from time to time, and numerous supplemental acts have been passed, as well as a number of acts, relating individually to the various districts that have been organized. The more important of the recent amendments and supplemental acts have had to do with financial aspects and state control.

Entirely aside from any value that may be attached, from an academic standpoint, to a rather full statement of an important movement in the economic development of the state, the value of a study of California irrigation districts is believed to be twofold. The disastrous mistakes made under the original California irrigation district act brought a tremendous economic loss to California, and a knowledge of those mistakes is the most effective preventive of a repetition of them. Secondly, irrigation districts are as a rule organized by people unused to effective business management, and the large general interest the state has in

fostering right development warrants furnishing to those who are operating, or who contemplate organizing irrigation districts, whatever assistance available means will permit.[1]

THE WRIGHT ACT OF 1887.

Briefly stated, this act sought to confer on farming communities powers of municipalities in the purchase or construction and the operation of irrigation works. Those powers included the right of eminent domain, the right to issue bonds against all of the real property within any area organized into an irrigation district, and the right to tax that property for the payment of the cost of any irrigation works acquired or built, and of their operation. "Fifty, or a majority of freeholders owning lands susceptible of one mode of irrigation from a common source, and by the same system of works," were authorized to propose the organization of an irrigation district before the board of supervisors of the county in which the lands included should be located. All electors in the area included were allowed to vote at district elections, but it was provided that at least two-thirds of all of the votes cast at an organization election should be favorable to organization in order to carry it, that a majority of all the votes cast at bond elections should approve the bonds submitted before they could be issued, and that two-thirds of all votes cast at elections on special assessments should approve such assessments before they could be levied. Full provision was made for the conduct of district elections, for meetings of boards of directors, and for their management of district business, for the issuance and sale of bonds, for the levying, equalization, and collection of assessments, including the sale of property for district taxes and its redemption within twelve months from date of sale, for the adoption of plans of works and for their construction, for the payment of all district expenses, etc. Boards of directors were given full authority to call special district elections on both the questions of issuing bonds and of levying of special assessments. District bonds were made payable in installments from the eleventh to the twentieth year after issue and were to bear

[1]The data presented in this report have been gathered from time to time, during a period extending over fifteen years, and to an extent that might not have been warranted in connection with a movement less closely related to the agricultural development of the state than the irrigation district movement has been, and still is. Many connected with the early history of districts organized under the Wright act, and from whom data were obtained by letter or by personal interview fifteen years ago, are no longer living, and while all of the information gained from them and others could not be included in this report, as complete histories of each of the forty-nine Wright districts formed as the available data have made possible have been filed with the State Department of Engineering at Sacramento. The writer has been assisted from time to time in gathering data about the old districts by the following: Wells A. Hutchins, R. M. Gidney, A. L. Cowell, Miss M. J. Shields, H. J. Quayle, and Harry Barnes. Mr. Wells A. Hutchins has also assisted materially in reviewing court decisions affecting irrigation districts, and the irrigation district legislation passed in California.

PLATE I.

CALIFORNIA IRRIGATION DISTRICTS ORGANIZED UNDER THE WRIGHT ACT OF 1887.

1. Happy Valley
2. Orland
3. Kraft
4. Orland Southside
5. Central
6. Colusa
7. Browns Valley
8. Modesto
9. Turlock
10. Madera
11. Sunset
12. Huron
13. Selma
14. Alta
15. Tulare
16. Tipton
17. Tule River
18. Kern and Tulare
19. Poso
20. Neenach
21. Amargoza
22. Palmdale
23. Manzana
24. Little Rock Creek
25. Big Rock Creek
26. Santa Gertrudes
27. Vineland
28. Glendora
29. Pomona Orange Belt
30. Strong
31. Walnut
32. Rialto
33. Olive
34. Citrus Belt
35. Grapeland
36. East Riverside
37. Alessandro
38. Elsinore
39. Perris
40. Murrietta
41. San Jacinto and Pleasant Valley
42. Riverside Heights
43. Anaheim
44. Escondido
45. Fallbrook
46. Linda Vista
47. Jamacha
48. San Marcos
49. Otay

Sketch map of California showing location of irrigation districts formed under the Wright Act of 1887.

interest at the rate of 6 per cent, and it was provided that bonds should not be sold for less than 90 per cent of their face value. In short, the act sought to clothe farming neighborhoods desiring irrigation with full authority at law to acquire by condemnation or otherwise all water rights and irrigation works that a majority of the freeholders and two-thirds of the electors voting in any district election in such neighborhoods should decide in favor of, with the taxing power of the state conferred upon such neighborhoods for financing their acquirement and operation.

ACTIVITIES UNDER THE WRIGHT ACT.

Organization of irrigation districts followed quite rapidly after the passage of the Wright act. The act was approved March 7, 1887, and before the end of that year Turlock, Modesto, Orland and Central districts had been formed, in the order named. Seven organized in 1888, including Browns Valley, Madera, Alta and Poso; six in 1889, including Tulare, Anaheim and Escondido; eleven in 1890, including Selma, Rialto and Perris; thirteen in 1891, including Sunset, Tipton, Alessandro, Fallbrook, Linda Vista and Otay; three in 1892; four in 1893, including Walnut; and the last, Amargoza, in 1895—in all forty-nine. From 1887 to 1893 petitions were also filed for the formation of ten more, in five of these cases the question of organization reaching a vote and being defeated.[1]

Because so few of the districts organized under the original Wright act succeeded and because so many were colossal failures, an impression has grown up that nearly all of them were speculative and fraudulent and that practically all defaulted. If this impression were justified it might not be considered in the interest of irrigation district development to delve too closely into their history, but rather to pass them over as of no live interest at this time, even at the expense of covering up an interesting phase of California economic history. But a careful study of all of the facts available fails to support such an impression. Dishonest and fraudulent districts there undoubtedly were—districts wholly speculative and with neither physical nor agricultural, nor even moral, justification. Nevertheless, in spite of the speculation and the dishonesty and the repudiation of some of the districts, and also in spite of the fact that only eight districts out of the forty-nine organized are now operating, the movement embodied in the irrigation districts organized from 1887 to 1895 was in its final results essentially constructive and forward, and as such is full of suggestion to those concerned in irrigation managed under the district form of organization.

A statistical list of the original Wright irrigation districts is given in the addenda. It does not seem wise twenty to thirty years after

[1] A list of these proposed districts is given in the addenda.

they were organized to attempt to classify them according to their feasibility. Some that were not feasible when organized would be feasible now. A number would have been feasible on a much smaller scale than attempted. Some had hardly an element of justification. Some were entirely feasible and still failed from general adverse conditions. One or two of those still active have never really succeeded.

Nor does it seem conclusive to classify these districts geographically, or according to their success or failure. While those organized in Sacramento and San Joaquin valleys, for instance, were mostly free from grossly speculative features, and while many of those organized in southern California were of a directly opposite nature, districts formed in all three of these general subdivisions of the state had important features and interests in common.

In order to learn the most from these old districts it therefore seems best to consider them from the point of view of what seems to have been their purpose. Thus classified they might be grouped about as follows:

Districts essentially nonspeculative and formed to meet a bona fide demand for new irrigation works: Orland, Kraft, Orland Southside, Central, Colusa, Browns Valley, Modesto, Turlock, Huron, Tipton, Tule River, Kern and Tulare, Poso, Amargoza, Neenach, Palmdale, Pomona Orange Belt, Olive, Grapeland, East Riverside, Elsinore, San Jacinto and Pleasant Valley, Riverside Heights, Escondido, Fallbrook, San Marcos, Otay. (27)

Districts essentially nonspeculative and formed wholly or largely for reorganization or improvement of existing systems: Happy Valley, Madera, Selma, Alta, Tulare, Santa Gertrudes, Vineland, Glendora, Strong, Walnut, Anaheim. (11)

Districts essentially speculative: Sunset, Manzana, Little Rock Creek, Big Rock Creek, Rialto, Citrus Belt, Alessandro, Perris, Murrietta, Linda Vista, Jamacha. (11)

Nonspeculative Districts Formed to Meet a Bona Fide Demand for New Irrigation Works.

Of the twenty-seven districts placed in this group, many offer but little, if anything, of particular interest. Orland, Kraft, Orland Southside, and Colusa were merely unsuccessful attempts to accomplish what all of the smaller and many of the larger resident farmers wanted, but against which there was sufficient opposition to prevent conclusive action. In the main they were merely ahead of their time and victims of neighborhood lethargy and bickering. A portion of the land included in Orland, Kraft, and Orland Southside districts, and the water supply they counted on, are now embraced in the Orland project of the United States Reclamation Service. Huron, Tipton, Tule River, Kern and Tulare, Amargoza, Neenach, Palmdale, Pomona Orange Belt, Elsinore,

San Jacinto and Pleasant Valley, Riverside Heights, Fallbrook, and San Marcos districts but represented ill-advised efforts to obtain water where in most instances there was no sufficient or stable supply. Olive covered only a very small area which, after confirmation of the organization and the bond issue voted, it was later thought best to supply with water by other means than a district organization. Grapeland district was prevented from consummating its plans largely through inability to obtain title to its proposed water supply in advance of undertaking development. It spent a large amount of money in the light of the best engineering data available, and about 1,000 acres of orchard is said to have been planted in the faith that the district would succeed, but an adverse court decision gave others superior rights to 2,700 inches of water from Lytle Creek and the district failed. Bonds traded by this district for groceries were later held invalid. East Riverside district had all of the elements of success, was efficiently managed, built one of the first irrigation pumping plants in California, and has been eminently successful as an irrigation venture, but owing to difficulties in collecting district taxes before irrigation water was made available, defaulted its bond interest and found it best to reorganize into the Riverside-Highlands Mutual Water Company. All of the land of the old district is now watered by that company and the value of citrus groves established on that land is estimated by a well-informed banker at $2,000,000.00.

CENTRAL.

This district was organized November 22, 1887. Entirely feasible physically it was still a disastrous failure because of the legal and financial troubles that beset all of the districts in the early nineties, but most of all because the forced irrigation of the great holdings included, averaging 870 acres for the entire district and with forty owners holding an average of 2,225 acres each, could not possibly succeed under settlement conditions existing then or even now.

The petition for the formation of Central irrigation district was signed by 64 (supposed) freeholders and was accompanied by the objections of nine nonresident landowners whose attitude in a way seems now to have forecasted the failure of the undertaking. Still engaged in the "bonanza" grain growing of the earlier and more remunerative period when both yields and prices were higher, they conjured up visions of ruin with the bringing in of irrigation water. Irrigation would be bad for fruit, they said. It would even produce chills and would be a detriment to alkali lands. And besides, the irrigation of wheat and barley was not a success, anyway. All of the lands included, they averred, were not irrigable from the same source, the boundaries of the district were improperly described, and the Wright act was unconstitutional. Further, these objectors intended in the near future to include

their lands in an irrigation district of their own which would include their residences so that they would have a voice in the proceedings. When election time came the opposition mustered only 51 votes out of 322 and organization prevailed.

Unlike many of the Wright districts, Central irrigation district started with a relatively complete engineering outline. The estimated cost was $638,900.00, and to meet this cost a bond issue of $750,000.00 was authorized by a vote of 189 to 36.[1] Bonds to the amount of $150,000.00 are said to have been sold for cash and for a time the district had ample funds with which to meet contract installments. The market for bonds, however, soon became sluggish, and there were no buyers. Therefore, outside of small blocks given for engineering and legal services, rights of way, and preliminary purposes, the balance of the issue was mainly turned over to the superintendent of construction by nominal sale and by him disposed of to contractors on the best terms he could get. In these various ways a total of about $570,000.00 of the bonds were put out. While the method of financing construction that was adopted carried the work forward for a few years, the time came when contractors would no longer accept the bonds, and in order to bolster up the market a special report on the project was made in 1891 by a consulting engineer of wide reputation who was then largely engaged in reporting favorably on California irrigation districts. The district still remained, however, in financial distress, the opposition continuing their fight against it. In October, 1893, in order to clear up legal uncertainties and thus to stimulate bond sales, the district board brought confirmation proceedings under the then recently enacted statute permitting such proceedings. The superior court granted the confirmation sought by the directors but the old opposition, now ninety-one strong, appealed to the supreme court and finally succeeded in obtaining a decision that the organization proceedings of the district were illegal and null and void.[2] In a previous case[3] Central irrigation district had been upheld, but on other grounds, the correctness of which

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[1] In 1891 the estimated cost was raised by the consulting engineer to $940,364, and an additional bond issue of $250,000 recommended. The justification for this increase was said to lie in the omission of allowances for organization, rights of way, and litigation in connection with construction, the three items amounting to $181,000; in an increase in the cost of excavation from 8.5 and 8.75 cents per cubic yard under the first contracts to 13.5 and 15.5 cents in 1891, and to unexpected and excessive costs of rights of way, in one case reaching as high as $212 per acre, with the usual rates $50 to $70 per acre.

[2] *In re Central Irrigation District*, 117 Cal. 382.

[3] *Central Irrigation District* vs. *De Lappe et al.*, 79 Cal. 351. In this case *mandamus* was sought to compel the secretary of the district to sign the bonds, one of the property owners of the district being allowed to intervene. A number of objections to the district were raised, including objections to the description of the district in the organization petition, to the form of the bond filed by the petitioners, to the manner of publishing the petition, to modifications in the district boundaries made by the supervisors, to the manner of publishing the proclamation of the organization election, to the time of establishing the voting precincts, and finally to the form of the bonds. All of these questions were decided favorably to the district both in the lower court and on appeal.

PLATE II.

Fig. 1.—Central Canal, originally built by Central Irrigation District, as reconstructed near Willows.

Fig. 2.—Pumping Plant of Sacramento Valley Irrigation Company at head of Central Canal.

was not questioned in the later case. The main points of the later decision were that the organization petition of 1887 was not properly signed, and that the signers of an organization petition must be *bona fide* owners of agricultural lands desiring to improve their lands by irrigation, and not merely the owners of town property and lots, as was the case with many of the signers of the Central irrigation district petition. While holding that bond sales made subsequent to this decision would be null and void, the validity of bonds already issued was not considered. In conformity with the decision the matter went back to the lower court and the new decree of the lower court, rendered March 1, 1902, was never appealed.

The adverse decision of the supreme court above cited put an end for all time to any thought of continuing the old undertaking, and outside of a brief formal activity in 1902 and 1903, for the purpose of leasing Central canal, no effort has been made to revive the old organization. Work on the system had practically ceased by 1891. At that time, while about 40 miles out of a total of 61.35 miles of main canal planned had been built, the system was not continuous and so could not be utilized; nor had any headworks been constructed, thus preventing the running of water in the portion of the canal that was ready to receive it. The leasing of Central canal January 6, 1903, had for its purpose the placing of the old district system in the hands of interests that proposed to utilize a portion of it for conveying water to lands along Sacramento River wholly or largely lying outside of the old district. This lease was made to W. M. Sheldon and was for a term of 50 years. Some years previously, but after the failure of the district, E. D. Beckwith had made filings on Sacramento River and had planned to utilize a portion of Central canal in connection with his appropriation. Lacking capital, he interested Sheldon, and these two, after the execution of the lease of the canal, formed the Sacramento Canal Company, which later was taken over by the Central Canal and Irrigation Company, and finally by the Sacramento Valley Irrigation Company. From this point forward the history of Central irrigation district becomes merged with the history of the Sacramento Valley Irrigation Company and of its subsidiary, the Sacramento Valley West Side Canal Company.[1] When these companies were organized it was supposed that Central irrigation district was finally entirely eliminated, in so far as its legal existence was concerned. The Sacramento Valley Irrigation Company gathered up most of the widely scattered bonds at a cost to it of 35 cents on the dollar, including accrued interest, and as one of the conditions of

[1] Through the agency of these two companies Central canal has been reconstructed and extended, water has been made available to approximately 100,000 acres of land, and a considerable irrigation development, including irrigation by pumping from wells, has taken place. Settlement, however, has not progressed very rapidly, and further reorganization, after financial difficulties, is now in process.

options secured on a large acreage of land in the old district, it agreed to guarantee lands not purchased under such options against any lien for these bonds. Later a compromise was sought to be entered into with the landowners by which certain concessions should be made to the company in rights of way and certain other matters, in return for the destruction by the company of all of the old bonds held by it. Litigation brought on by those opposing this compromise, however, has entirely upset previous theories as to the existence of the old district and as to obligations incurred by the new company in taking over the old Sheldon lease from the district and a congressional grant of a right to divert 900 cubic feet of water per second from Sacramento River obtained by the Central Canal and Irrigation Company April 16, 1906. The final decision in this litigation, rendered by the supreme court April 29, 1915,[1] held among other things, that lands within the old Central irrigation district constitute the primary territory to which the original public use contemplated by the district and by the grant of congress extends and continues, and that when demanded such lands must be served with water from the new system before it can lawfully be taken for use on outside lands. Thus at this late date the old district comes in to complicate operations of the new companies that were organized on the theory that the old district was no longer of moment and could not in any way limit the delivery of water to the lands outside of it purchased and later largely sold by the various companies succeeding Sheldon and Beckwith. An even later decision of the California Railroad Commission, rendered June 14, 1915, that holds the Sacramento Valley West Side Canal Company to be engaged in public service, while not in any way affecting the old district, so changes the basis of water distribution by the new companies that ultimate entire reorganization, probably under one or more new districts, now seems altogether probable.[2]

BROWNS VALLEY.

Browns Valley irrigation district was started and its construction undertaken without adequate engineering study. A first issue of bonds in the amount of $110,000.00 was hastily voted and "sold" to a dummy purchaser (said to have been a janitor in a San Francisco bank) and by him traded to contractors at a reported price of 60 cents or less on the dollar. A second issue of $30,000.00 voted in 1892 was similarly disposed of, the net result from the two issues being headworks in North Yuba River, nine miles of flume, twenty-five miles of main canal, and some miles of laterals. Instead, however, of having works capable of watering nearly 45,000 acres, only about 4,500 acres could be covered,

[1] *Byington et al.* vs. *Sacramento Valley West Side Canal Company et al.*, 148 Pac. 790.

[2] Since the above was written appeal from this decision has been taken to the United States court.

due to the uneven character of the ground. By the time these works were ready for use legal and financial difficulties had come on. Taxes were defaulted and resisted in the courts and while the earlier cases taken to the courts were won by the district or settled out of court, lower court decisions rendered in 1899 held the bond issue and all subsequent proceedings relating to them null and void. A similar outcome attended confirmation proceedings brought by the directors and other cases involving tax sales, and in 1902, after the district had been struggling along in spite of all difficulties and adverse decisions, and in some way getting a little water to the farmers, an unsuccessful attempt was made through *quo warranto* proceedings to stop any further corporate existence of the district, the case,[1] after going to the federal court on a question of constitutionality, finally being dismissed. Failure of the district to pay bond interest at last got the bonds into the federal court, where, on May 18, 1905, judgment was given conclusively establishing the district's obligation. After this judgment the futility of further opposition by the district was clearly apparent, and in the following year a compromise agreement with the bondholders was effected on a basis of 30 cents on the dollar for both principal and interest. The amount necessary to meet this compromise was $66,633.10, involving a levy of $21.60 per $100.00 on a total assessed valuation of $308,500.00. This assessment, although voluntary, was quite promptly paid by most of the landowners, and in June, 1915, the indebtedness had been met on the 30-cent basis so far as presented for payment.[2]

During the decade and a half of litigation following the construction period in this district little if any attention was given to care and operation of the canal system, and about the only land irrigated was a little at the lower end. A few years ago the district entered into an agreement with a power company, now succeeded by the Pacific Gas and Electric Company, under which agreement in return for power privileges on the canal, the power company agreed to maintain the system to its original capacity without cost to the district. Thus freed from the burden of maintenance, and with the old indebtedness compromised, the district took a fresh start and after twenty years of trouble began to realize something of the original aims of its organizers.

TURLOCK AND MODESTO.

These two districts were the first to be organized under the Wright act. The conditions around Modesto which led up to the passage of the Wright act have already been referred to. Practically the same situation existed around Turlock, except that a greater proportion of

[1] *People ex rel. Brady* vs. *Browns Valley Irrigation District et al.*, 119 Fed. 535.

[2] On June 9, 1915, all but about $1,700 of the voluntary levy had been collected and bonds and coupons amounting to about $6,500 were still unpresented for payment.

the voting population in Modesto district than in Turlock district resided in the towns. For instance, of 700 who voted for the formation of Modesto district, 526 lived in the town of Modesto, while of the negative votes, only 25 out of 181 were cast by residents of Modesto. In Turlock district organization was carried by 291 to 72.

The essential condition in both of these two districts was the failure of dry grain farming to continue a profitable industry, except on a scale possible to the large landowners only, and to them it was only profitable on a greatly reduced scale. Those who could still be successful because of their large acreages were mostly opposed to any change, while those holding smaller farms and who felt the pinch of the decreasing profits were as a rule anxious for water. The town residents whose prosperity depended on the general prosperity of the community could clearly see the advantage of the more diversified and intensive farming that irrigation would bring.

Almost immediately after organization both Modesto and Turlock districts went promptly to work to formulate construction plans, and as soon as preliminary surveys had been made and reports based on them filed with the boards of directors, both districts proceeded to vote what they believed to be sufficient bonds to complete the systems proposed; and with these bonds voted, both districts undertook at once to make final surveys and let contracts. From the start, however, neither district was able to market many of its bonds outright for cash, and both sold them mostly through third parties.

It was originally expected that these two districts should obtain their water supplies from different streams. Tuolumne River was the only available source for Turlock district, but for Modesto district there was a choice between the Tuolumne and the Stanislaus, and the latter was first chosen. The advantage of both districts taking water from the Tuolumne was soon apparent, and accordingly they joined in the construction of La Grange dam, which was completed in December, 1893. Before this time the insufficiency of the original Turlock bond issue had become evident, and a second issue of the same size as the first had been voted. The original issue of Modesto district had been larger and its construction fund was not exhausted until the middle of 1895; but in July of that year a second issue was voted there, also.

While both Modesto and Turlock districts had been organized by ample margins over the necessary two-thirds of those voting, the minorities against organization did not cease in their opposition. This opposition mostly paid the first district tax under protest, but their next step was to refuse to pay and to seek injunctions against the enforcement of collections through the tax sales provided for in the law. In both districts suits were early carried to the supreme court but both were declared by that court to have been legally organized.

In the case of Turlock district a friendly suit was brought to test the validity of the Wright act, this being a proceeding to compel the secretary of the district to sign the district bonds. In its decision given May 31, 1888,[1] the court held that the Wright act was constitutional, that irrigation districts formed under that act were *quasi* public corporations in the sense that the purposes for which they were organized were for the general public benefit, and that it was not necessary for their validity that the methods adopted for the levying and collection of assessments should follow exactly the mode provided in the constitution for the assessment and collection of taxes for general state purposes. The case involving Modesto district was a petition filed in 1889 to have the proceedings for the issue and sale of the district bonds confirmed.[2] The lower court had confirmed the organization of the district, and with certain exceptions its judgment was confirmed. Among other things, the case involved the notice of the confirmation proceedings, the matter of including the town of Modesto in the district, the exclusion of 18,000 acres from the district after the organization and after the decision of the board of directors to sell $800,000.00 in bonds, and the resolution of the directors to sell $400,000.00 of the bonds after changing the source of supply. Not satisfied with this decision, the opposition appealed to the United States supreme court, by which the case was finally dismissed November 16, 1896. In spite of these two supreme court decisions upholding the districts and the validity of the Wright act, many decisions enjoining the sale of land for delinquent district taxes were given in the superior court, although the first of these were generally favorable to the district. Some of those who sought relief from district taxes were normally friends of the districts, but in such straitened financial circumstances, owing to the depression of the early nineties, that they were ready to take advantage of every opportunity to escape financial obligation. Every year in Turlock district from 1895 to 1900 blanket or individual suits against tax sales were brought and temporary injunctions obtained, but no attempts were made to bring the suits to final issue. In November, 1901, however, an issue was finally joined between Turlock district and those fighting it in the case of *Baldwin et al.* vs. *The Board of Directors of Turlock Irrigation District et al.* This case originally involved merely a contest between the taxpayers and the district, but later almost the entire number of Turlock district bondholders intervened to defeat the injunction prayed for. The decision of the superior court held not only that there had been no material irregularity in the issuance of the bonds, but also that those in possession of them were

[1] *Turlock Irrigation District* vs. *Williams*, 76 Cal. 360.
[2] *Board of Directors of Modesto Irrigation District* vs. *Tregea*, 88 Cal. 334.

bona fide holders thereof and that hence the bonds were valid obligations of the district, even if there had been irregularity in issuing them. This was the last suit of importance in which the legality of Turlock district and its obligations were involved and from the time of the decision the people of the district faced forward rather than backward.

During most of the time that Turlock district was involved in litigation it had sought to continue construction and when the decision in the Baldwin case came, except for two of the main laterals, the heavy work of construction was already completed, and some water was ready for delivery to the district. This result had not, however, been accomplished without great effort, and without the failure of several contractors and very great difficulty in financing the work under way. In Modesto district there was less work to do and there had, perhaps, been more rapid progress in the earlier years of construction. By July, 1895, the headworks, the flumes in the upper nine thousand feet, and all earth work down to the district near Waterford, a distance of approximately twenty miles, had been completed. As in Turlock district, tax sales had been enjoined by the lower courts, but those in favor of the enterprise were able to keep control and to continue work until the spring of 1896, when the opposition elected two members of the board of directors pledged to use all possible effort to block progress. Shortly thereafter two of the old members of the board who had thus far supported the district resigned and two new directors were appointed who were with the opposition. Under the rule of the "antis" all work on the system was suspended for four years and no assessments levied to pay interest on outstanding bonds. A defense association was incorporated to strengthen the opposition, but times had improved and gradually sentiment changed, and in 1901 a new board was elected with at least three members in favor of going ahead. By this time the constitutionality of the Wright act had been upheld in the United States supreme court[1] and the opinion was growing in the district that there was no escape from the outstanding obligations. The bonds of the district were then valued at about forty or fifty cents on the dollar and unredeemed interest coupons could be purchased for 30 per cent of their face value. During this gradual change in sentiment some of the bondholders had sued in the United States courts for the defaulted interest and in August, 1901, a deputy marshal appeared with a mandate from the circuit court commanding the district to levy an assessment to pay an interest judgment against the district. With the arrival of this mandate from the United States court, Modesto district found itself substantially in the same situation that confronted Turlock district after the decision in the Baldwin case, and it also set about making plans for reorganization. As a first step a popular subscription of about $1,500.00 was presented to the new board of directors

[1] *Fallbrook Irrigation District* vs. *Bradley*, 164 U. S. 112.

for the purpose of making such surveys and studies as might be necessary to determine the cost of completing the irrigation system that had been started. In October, 1901, plans for going ahead were submitted and an assessment of $50,000.00—the first since 1896—was levied for the payment of outstanding interest.

When the Wright act was revised in 1897 a supplemental act was also passed providing for the funding of irrigation district indebtedness, and in the new turn affairs had taken in Turlock and Modesto districts, it was clear both to the districts and to the bondholders that they should proceed under this law. Accordingly an agreement was drawn up between each district and its bondholders under which the old indebtedness should be retired and a new financial start made by each district. Including interest and principal on outstanding bonds and floating debts, the total indebtedness of each district now reached approximately $1,350,000.00. To meet its indebtedness Turlock district issued 5 per cent bonds in amount of $1,082,000.00, or at the rate of 80.5 cents on the dollar, and in Modesto district funding bonds were carried by vote of 433 to 24, sufficient to pay the original indebtedness as it stood in January, 1902, on a basis of dollar for dollar, less a refund to the district of five years' interest on the funding bonds.

From the funding of their indebtedness in 1902, all doubt as to the future success of Modesto and Turlock districts disappeared, and both districts set resolutely about getting water to the landowners. Having its principal work already completed when the compromise was effected with the bondholders, Turlock district was already delivering water, and within three years water had been carried to 20,000 acres. Modesto district, however, had first to complete its system. In March following the compromise plans for building the distributing system within the district and for repairing the upper works were adopted and by July contracts for all of this work had been let. Through the cooperation of the bondholders and public-spirited citizens within the district necessary funds were raised and on October 6, 1903, the work under the last contract was accepted. Before the season of 1904 was over, nearly 7,000 acres had been irrigated and a start had finally been made in changing Modesto district to the community of diversified farms contemplated when the author of the Wright act drafted that act fifteen years before.

POSO.

Among the California districts formed in a *bona fide* effort to build entirely new irrigation systems the three whose histories have just been given were the most conspicuous. Central district, as was pointed out, failed largely because decades ahead of its time, and because the larger holdings and the larger rainfall there made dry grain farming still profitable over a considerable portion of the district's area. Turlock

and Modesto districts, on the other hand, succeeded in spite of obstacles because with their smaller rainfall and their smaller average holdings, the declining wheat market made the old-style dry farming no longer tolerable. For all three of these districts the water supply was ample and in each there was a sufficient farming population to be fairly representative of those to come. Poso district represented most strikingly a third type in this group, the type that failed because of physical rather than of human difficulties. Probably no district formed in a well-meant attempt to accomplish something was more ill-advised than it was.

With all of its 40,000 acres, Poso district mustered only twenty-six voters at the organization election, and with these twenty-six voters the wish for a water supply was entirely the father of the effort to obtain it. Even a half-million dollar bond issue was voted without any prior surveys or engineering estimates. Then engineers were employed and a ditch system laid out, and so hopeful were the people that they issued a glowing prospectus setting forth, among other things, that the district had "an undisputed, bountiful, invaluable water supply, perfectly practical project, planned for the procurement of the same; ample storage facilities, economical system for distribution, first-class drainage, rich, deep soil, and unexcelled climate." The county assessment roll, when the district was organized, gave the district lands a value of $502,000.00, but the district looked into the future and claimed a value, without improvements, "when the district works are completed," of eight times that amount.

The water supply for Poso district was to come from Poso Creek and the proposed works included a masonry dam 40 feet high, a 2.5-mile all-rock cut, 94 miles of canal, and two reservoirs, together holding "2,647 million gallons," "sufficient for ample irrigation of the district." After using $60,000.00 of the bonds for miscellaneous purposes the district agreed to turn over the remaining $440,000.00 to contractors for a completed system of works, to be finished within one year. Under this arrangement an inferior dam of some sort was constructed, also several miles of wooden flume, and a large canal was carried out some distance into or toward the district. No record has been found of the exact amount of the bonds that were actually disposed of, but it is presumed that most of them were, when finally it dawned upon the people who, without any experience either in irrigation or in large financial affairs, had rushed into the enterprise with a blind enthusiasm, that the water supply in Poso Creek was wholly inadequate for their needs and totally undependable. When, in the midst of their disappointment over the failure of the water supply, an unexpected freshet carried out their dam, the enterprise utterly collapsed.

Few of the old irrigation districts were involved in more litigation than was Poso district. The organization of the district and the bond issue had been confirmed shortly after the bonds were voted. Several of the cases that went to the higher courts resulted in interpretations of the Wright act that had not yet been made. One of the decisions in these cases held that confirmation proceedings would estop an attack on the legality of an organization and of a bond issue confirmed, or in other words, that judgment in confirmation proceedings is binding on all the world until reversed on appeal or set aside by some direct proceeding instituted for that purpose.[1] In another of these cases it was held that public lands, of which the district was in considerable part made up, could not be included in an irrigation district, that neither the state nor its agencies could impose assessments thereon, and that the sale or patent thereof after issuance of bonds could not operate to charge the land with any pre-existing liability not assented to by the government or its grantee.[2] In a federal court case brought to *mandamus* the supervisors of Kern County to levy an assessment to cover an interest judgment, the *mandamus* was allowed and later confirmed.[3]

In spite of the failure of the irrigation works undertaken by Poso district and the abandonment of the district enterprise the lands included in the old district have gradually increased in value and the owners of these lands have long realized that some kind of a settlement must some day be made with the bondholders. This settlement is now in course of consummation, an investment company which has acquired most of the old bonds having offered in connection with a title insurance company to insure lands in the district against liability on account of the old bonds on payment of $11.00 per acre, or a little less than the original bonded indebtedness exclusive of interest. While only a few hundred acres included within the old district are now being watered, up to November, 1914, settlements had been effected on the above basis covering 16,715 acres.

ESCONDIDO AND OTAY.

The Wright act, as has already been indicated, was an outgrowth of conditions in Sacramento and San Joaquin valleys under which the larger riparian owners and the larger landowners were holding back irrigation development. Almost as soon as the act was passed, however, other communities recognized in it a means of irrigation organization of wide application. As the succeeding pages of this historical sketch will show, the southern counties of the state most largely undertook to utilize the act, thirty of the forty-nine districts organized having

[1] *Crall* vs. *Board of Directors of Poso Irrigation District*, 87 Cal. 140.
[2] *Nevada National Bank of San Francisco* vs. *Poso Irrigation District*, 140 Cal. 344.
[3] *Nevada National Bank of San Francisco* vs. *Board of Supervisors of Kern County et al.*, 91 Pac. 122.

been in counties south of Tehachapi. Of these thirty southern districts six were formed in what now constitutes San Diego County, and of these six, Escondido and Otay, among those that seem to have had at least some justification, are of most interest.

Both Escondido and Otay districts, although considerably larger than they should have been, began with sufficient available water to justify irrigation development. Both were mainly started by the smaller landowners and openly or tacitly opposed by the larger ones. In Escondido, which contained the larger population, energetic effort carried the enterprise all but to success, in the face of the bitterest and most vicious opposition. In Otay, on the other hand, discouragement came when the estimated costs were made public, and constructive activity soon ceased.[1]

Escondido irrigation district was in the first instance undertaken with but little open opposition, only fifteen votes having been cast against organization. About one-half of the land, however, was still owned by Escondido Land and Town Company, from which most of the residents of the district had previously purchased. With only "fifty or a majority of the holders of title, or evidence of title," to the lands to be included necessary to initiate a district, it was possible to get started without the acquiescence of the Land and Town Company, and the laying out of an irrigation plan and the issuance of bonds to carry it through, and also the construction of sufficient part of the system to irrigate about 1,000 acres, seem to have been accomplished without great difficulty. But the smoldering opposition grew along with a realization that the system planned was insufficient to water all of the irrigable lands of the district. The first real trouble came when interest on the bonds was due, the Land and Town Company refusing to pay its district assessments, amounting to about $11,000.00 per year, and others following its example. Every effort was made by the opposition to dishearten the people and by discouraging prospective land buyers, to reduce the ability of the smaller landowners to meet their district taxes and thus increase the growing spirit of repudiation. Bond issues aggregating $350,000.00 had been voted and sold through the contractor at 90 and 91 and about $320,000.00 had been expended for construction and water rights.[2] With this money spent and interest constantly accruing, and with the larger landowners refusing to pay district taxes, the failure of the enterprise was inevitable. While a few of the land-

[1] The area included in Otay district was 44,000 acres, mostly of the rolling character so largely used in citrus culture. When the district was formed it was thought that $5 per acre would provide a water supply, Moreno reservoir being planned as the source. The engineer's estimate for the cost was $1,200,000, or about $27 per acre. The engineer's report expressed confidence that the sum suggested would "provide for the district so abundantly as to bring to it a degree of prosperity" that would permit it "to afford any further refinement in distribution or amplification of capacity or supply that may be found necessary or desirable."

[2] The actual price said to have been paid by the real bond-buyer to the contractor was 75.

owners paid their taxes in full even up to the time of disorganization, most of them ceased paying after the second and third years. In order to secure its two bond issues the district executed trust deeds conveying the whole water system to a trustee and in default of interest the trustee had taken over the system and was operating it on water tolls, although he was estopped from foreclosure and sale of the system by supreme court decision holding the trust deeds invalid.[1] After a long period of depression, during eight years of which it is said not a house was built in Escondido, an agreement was secured with the principal bondholders by which, for a consideration of $200,000.00, with interest from the date of the agreement, the old debt then, counting interest, amounting to something over $500,000.00, was to be canceled. Of this $200,000.00 consideration $50,000.00 was to be used to repair parts of the system so that by getting water certain of the landowners who had previously held out would be ready to join in the proposed settlement. To carry out the settlement the Escondido Mutual Water Company was organized, each landowner taking stock at one dollar per share in proportion to his individual quota of district indebtedness. With this accomplished the district was disorganized, and in the midst of great rejoicing the bonds were burned September 9, 1905.[2]

The human situation in Otay district was wholly different from that in Escondido. Opposition at Otay was active from the beginning and is said to have been led by a defeated candidate for the first board of directors and by owners of hillside vineyards who did not want irrigation, as well as by a number of vegetable growers. The district got into trouble at once through mismanagement. A bond election that had been proposed was stopped when the estimate of the engineer who had been employed indicated that the cost of works would be much larger than anticipated. Shortly thereafter the directors undertook, without a special election, to levy an assessment of $9,000.00 to pay outstanding debts and continue the organization for another year, but on appeal to the courts the assessment was held invalid.[3] In the meantime a portion of the assessment had been collected but the district collector refused to turn the amount collected over to the treasurer, resulting in a suit against the collector for embezzlement of funds, and in another supreme

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[1] *Merchants National Bank of San Diego* vs. *Escondido Irrigation District*, 144 Cal. 329.

[2] One of those most active in supporting the district and finally in re-organizing it on the basis of a mutual water company recently stated that there was absolutely no excuse for the district not succeeding. The same water supply is now used and the dam in Von Sergern Canyon above Escondido is no higher than it was when the district was organized. While the mutual water company has made some improvements in the system, there is but little more land irrigated now than before the district disorganized. It is clear, however, that the mutual water company plan, under which the cost of irrigation is borne by those using the water, is fairer to all concerned than the old district embracing such a large area for which no water was available.

[3] *Woodruff et al.* vs. *Perry et al.*, 103 Cal. 611.

court decision.[1] A third supreme court case involving Otay district was that of *Decker* vs. *Perry*,[2] but no important questions were involved. In spite of the litigation the district directors continued to meet and before a majority had been elected, pledged "with God's help," to wind up the affairs of the district; they had voted themselves mileage and salaries amounting to over $2,500.00 and had contracted debts considerably exceeding that amount. On November 14, 1894, a vote was carried to petition the superior court for dissolution, but this was prevented by the unpaid creditors, for, although their claims had outlawed, and were no longer good in law, the court held that they still constituted claims in equity which would estop disorganization. With the exception of brief activity in 1910, when a new board of directors was appointed by the supervisors of San Diego County, and the land later included in San Ysidro district was petitioned out, Otay district has had no activity since then, and the district is still a legal entity.

Nonspeculative Districts Formed Wholly or Largely for Reorganization or Improvement of Existing Systems.

Of the eleven districts placed in this group, a number went through experiences of considerable interest. Happy Valley district was unimportant and was soon abandoned, a small cooperative company taking over the private system the district was formed to take over. Santa Gertrudes district was mainly formed as a means of financing the construction of a pipe line to replace a leaky flume. No one volunteered to take the $55,000.00 in bonds they voted, and while the district was waiting for something to turn up, it lost through nonuse the water right it started with. Selma, Vineland, Glendora and Strong are covered in the footnote.[3] Of the remaining five in this group, Alta, Tulare,

[1] *Perry* vs. *Otay Irrigation District et al.*, 127 Cal. 565.

[2] 101 Cal. unreported cases.

[3] *Selma.*—For some time prior to the formation of this district there had been water-right troubles along lower Kings River, chiefly involving claims of lower riparian owners. As a result the farmers under Fowler Switch and Centerville and Kingsburg canals found themselves threatened with water shortage. To better their situation they organized under the Wright act, including about 200,000 acres in their district, and from reading such records of the old district as are available it would seem to have been their intention to overcome the riparian owners almost regardless of how they should do so. Apparently, also, the farmer stockholders in Fowler Switch and Centerville and Kingsburg canals were quite willing to exchange their shares for district bonds, and at a sufficiently high price to arouse some local criticism. Real activity in the district, however, did not last long, for attempts to vote large bond issues failed twice in 1890 and again in 1891. Still those holding to the district idea continued the organization and succeeded in carrying assessments for a number of years, but apparently without accomplishing anything and with no clear purpose in view. Ultimately Fowler Switch and Centerville and Kingsburg canals passed into individual ownership under which they were operated on a water-right basis, and later passed into control of the Consolidated Canal Company, which united in one control the appropriation and riparian interests that had been in controversy. As early as 1891 an attempt had been made through *quo warranto* proceedings to have the district disorganized, both because it had failed to use the privileges and rights for which organized and because, in spite of the repeated decisions of the voters not to issue bonds, the salaries of officers were still being paid by means of assessments. The interesting phase of this attempt was the decision, affirmed by the supreme court (*People* vs. *Selma Irrigation District*, 98 Cal. 206) that the Wright

and Walnut are now active and their histories are therefore of some present importance. Madera and Anaheim districts both failed early, but because a new district is now proposed for Madera, and because Anaheim was one of the most worthy of the efforts under the Wright act that did not succeed, and also because the old Anaheim district was thoroughly typical of an important stage of general irrigation development in California, these two districts, along with the three that are still active, warrant fairly full consideration.

MADERA.

The history of this district has added interest because of the likelihood that, although the old district failed and was disorganized, the district form of organization is finally to prevail in the Madera community.

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act made no provision for judicially dissolving a district and that the court was without power to act. This decision led to the act of 1903 providing for such dissolution. (Statutes 1903, chapter V. *See, also*, amendments Statutes 1908, chapter 91; Statutes 1911, extra session, chapter 26, and Statutes 1913, chapter 39.)

Vineland.—This was a small district, the first of twelve organized in Los Angeles County, and is interesting both because of its present problematical status and because it indicates something of the handicap involved in uncertainty over water rights and in the lack of state regulation of water appropriations. The community that organized the district had been using some water from San Gabriel River, but increased diversions above, at Covina, Azusa, and Duarte, had reduced their supply. Bond issues amounting to $52,000 were utilized in purchasing water rights, in boring a 3,000-foot tunnel under the San Gabriel, and in constructing a cement-lined and pipe distributing system, both legal and engineering advice having guided the district in all they undertook. The tunnel under the San Gabriel, however, was so located as to withdraw water that otherwise would have passed on to the upper communities and on suit by them, affirmed by the supreme court (*Vineland Irrigation District* vs. *Azusa Irrigating Co.*, 126 Cal. 486) they were held to have rights superior to the district. Fortunately, prior to this decision the district had entered into agreement with a power company under which, in return for the district ceding to that company whatever rights it might have in San Gabriel River, the power company was to install a pumping plant in the district and furnish power for its operation. Under this agreement a well was developed giving about 100 inches of water (two cubic feet per second) so that the district got something for its effort and for the bond-buyers' money it spent. Since 1894, however, the district has defaulted in interest payments and so far as can be learned has done nothing in satisfaction of the bonds, which came due in 1910. The pumping plant (which has since been changed to a steam plant operated by the district) was managed under the district organization for a number of years, but being somewhat unsatisfactory, and irrigation districts by that time having come into rather bad repute, the board of directors resigned and no one voted at an election called to select successors. The former secretary has continued in possession of the records and on advice of attorneys the treasurer has continued to hold a balance of about $1,500 collected by assessment before the district was abandoned. From time to time interest coupons have been presented for payment, but this has been refused by the treasurer, he holding, on advice, that he could not make payment without giving preference to some of the claimants, and that he was authorized to pay out the money only on warrant from the district. Other than the case above referred to the district has not been involved in important litigation. Several suits were brought to annul tax sales by the district and to declare the bonds void. In two of these cases (136 Cal. 185, 140 Cal. 376) bondholders intervened. In the former case it was found that the bonds of the district were legally issued and that the tax sales in question were valid; in the latter case the action was dismissed. One suit was brought in 1903 to compel payment of bond coupons amounting to $1,356, but this was dropped on stipulation to resume after ten days' notice. It is said that about 2,000 acres is now being irrigated in the district, of which about 1,500 acres receives water from the well owned by the district. The water is handled by a local unincorporated co-operative company.

Glendora.—This district was formed, almost unanimously, to take over the Glendora Water Company, its organizers having mainly been landowners who had expected to obtain water from Glendora Water Company, but which that company seemed unable to provide. Agreement for the purchase of the Glendora system was entered into before the district was formed and it was intended also to develop water from tunnels back of Claremont. Misunderstanding in interpreting the agreement with the Glendora company resulted in that company actively opposing confirmation

Madera district was formed, and later voted an $850,000.00 bond issue, almost unanimously.[1] Opposition developed, however, as soon as confirmation proceedings were started. The superior court confirmed both the organization and the bond issue, but an appeal was taken by the larger landowners and the case sent back to the lower court for a new trial.[2] The attack on the organization concerned the validity of the organization petition and, in addition, the constitutionality of the Wright act was again attacked. Although deciding against the district in the matter of confirmation, the supreme court quite exhaustively reviewed and affirmed its previous decisions upholding the act.[3] Before this litigation was started the district had agreed on a plan of works estimated to cost $470,000.00, and steps had been taken to acquire the beds of Summit, Highland, Kellogg, and Shadow lakes, which it was proposed to use for reservoirs. With a view to purchasing the system of the Madera Canal and Irrigation Company the district had caused a valuation of the property of that company to be made, and proposed to purchase it for $100,000.00 in district bonds at par, but a definite offer either was never made, or was not accepted. While the successive boards of directors continued their efforts in behalf of the district,

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of the district and of its $170,000 bond issue. The lower court confirmed the district and the bonds but after appeal to and subsequent rehearing by the supreme court the lower court was reversed (*Cullen et al.* vs. *Glendora Water Company*, 113 Cal. 503) "for the reason that the board of directors of the Glendora irrigation district made no estimate of the amount necessary for any purpose" before calling the bond election. Among other points decided was one that where the supervisors had ordered the election of directors at large it was not necessary to provide more than one precinct in the election. Even before the decision in this case in 1896, the district plans had been practically abandoned and a mutual water company organized. The entire area within the old district boundaries is now irrigated by the mutual company.

Strong.—This district was unique in that it was organized to safeguard a water supply already available rather than to acquire a new one or to construct irrigation works. The lands embraced were part of the ranchito, near Whittier, formerly owned by Pio Pico and, since about 1855, served with water from San Gabriel River through Rincon ditch. Beginning about 1882, however, the owner of Puente Rancho on which Rincon ditch headed and through which it passed, had challenged the right of the lower users to the ownership of the ditch and for a number of years had exacted rental. Being dissatisfied with this arrangement and not having the right of condemnation as private users, the irrigators under Rincon ditch formed Strong irrigation district in the spring of 1893 and in the following year began proceedings for a decree of condemnation. That particular suit was not pressed, but another one was brought by individual landowners in an effort both to establish a prescriptive right to the use of the ditch and a right to the water carried. The lower court decided favorably for the landowners (*Strong et al.* vs. *Baldwin*, 137 Cal. 432), but its decision was reversed. In the second trial, however, the landowners were upheld both in the lower court and on appeal (154 Cal. 150). Activity by the district ceased in 1898 while the litigation was still pending, but the community has continued to operate Rincon ditch by means of a mutual water company, although as the full acreage of the district was irrigated when the district was formed, there has been no increase. One of the reasons given for letting the district organization lapse was dissatisfaction on the part of some of the users over the levying of uniform assessments throughout the district, as provided for in the Wright act. Users near the head of the ditch felt that they should not be obliged to pay as much for maintenance as those further down. Under the mutual plan of operation the ditch was divided into three sections and the charge made smaller at the upper end and larger at the lower end than in the central section.

[1]The vote on organization was 292 for and 5 against; that on the bond issue, 243 for and 7 against.

[2]*In re Bonds of Madera Irrigation District*, 92 Cal. 296.

[3]See *Turlock Irrigation District* vs. *Williams*, 76 Cal. 360, and *Central Irrigation District* vs. *De Lappe et al.*, 79 Cal. 351.

levying assessments for preliminary expenses in 1889, 1890, and 1891, continued opposition of the larger landowners and resulting litigation finally discouraged the people, and after a failure to compromise in 1891, propositions to disorganize and to levy an assessment of 16 cents on each $100.00 for clearing off all indebtedness were overwhelmingly carried, and the district dissolved April 18, 1896.

It seems very evident that Madera irrigation district failed because of an effort to accomplish too much, seeking an ideal rather than the best practicable system. When the district was formed Madera Canal and Irrigation Company was irrigating an area since estimated at from 5,000 to 12,000 acres, and 5,000 acres more or less was receiving water from White House Canal, the remaining area in the district being entirely in grain or pasture. Yet, without the cooperation of the larger landowners, and without reaching any agreement with those holding riparian rights on Fresno and San Joaquin rivers, the people of the town of Madera and those holding tracts of 20 to 320 acres surrounding it sought to finance and organize an irrigation system larger than any that had ever been constructed in the state. Had the people within reach of Madera Canal been able to concentrate on the purchase and improvement of that canal, their condition would have been very much better than it is at present. As in the case of other communities which attempted to operate under the Wright act, however, the community overestimated their power over the opposing and more strongly intrenched minority. The failure of the earlier enterprise has probably decreased the supply from Fresno River to which the Madera community can maintain a claim, yet that failure should render it easier for the present community to agree upon and to carry through a more feasible plan. During the past few years the question of forming another irrigation district has again come up and it is again proposed both to acquire the system of the Madera Canal and Irrigation Company and to obtain water from San Joaquin River, partly by storage above Pollasky. While it is planned in a general way to cover about 150,000 acres, the proposition to organize has not yet been sufficiently worked out to enable the community to know just what is feasible, nor have water-right questions on Fresno and San Joaquin rivers been sufficiently cleared up to indicate what is possible to the proposed new district in the way of an undisputed water supply.[1]

[1]Since the above was first printed, Webster irrigation district, comprising 15,000 acres lying generally within the proposed new Madera district, has been formed. This is a pumping project from wells near San Joaquin River, and has no connection with the proposed larger project.

ALTA.

One of the most interesting things about this district is that it succeeded, although with the usual financial difficulties before getting securely on its feet, and only after a compromise with the bondholders and a financial reorganization in 1902.

Alta district appears to have been promoted by the '76 Land and Water Company, which had built the '76 Canal, and was already furnishing water to about 19,000 acres, selling water rights at the rate of $200.00 for each 40-acre tract. Including the reimbursement to the holders of water rights under the canal for the amounts paid by them for water rights, the district exchanged $410,000.00 in bonds for the '76 system and utilized additional bonds to the amount of $133,000.00 in improving the old canal and in building laterals. Not being able to dispose of their bonds for cash, and being advised by their attorneys that they could not exchange them for work, the district made informal agreements with contractors to purchase the branch canals after completion by them, the work to be done in a manner satisfactory to the district. During the dark days of the district in the nineties, however, when taxes were being contested, this novel irregularity in the disposal of bonds was the ground for a superior court decision August 12, 1898, that the bonds were void because no plan or estimate of the cost of the system of irrigation works was made by the directors before calling a bond election, and because the act of the district in surveying ditches and then having an understanding with certain contractors that after approval by the district those ditches would be purchased by it at so much per cubic yard amounted to no more than the employment of the contractors to do the work and was therefore illegal.[1] This decision, which was given in one of the suits brought by outside attorneys in their general campaign against the Wright act, did not, however, serve to invalidate the bonds, but merely added to the unsettled condition which was not finally cleared up until the district and the bondholders agreed to a refunding of the original bonds, of which $543,000.00 were outstanding, at a discount of 25 per cent. At the time of this refunding landowners in the district signed an agreement not to contest the new issue and that issue was confirmed by the superior court July 3, 1902. While the district failed to levy assessments for the payment of interest in 1898, 1899, and 1900, the interest defaulted in those years was paid with a discount

[1] This case was not appealed and no supreme court decision has been found covering this point.

of 25 per cent at the time of the compromise. Since the compromise and refunding Alta district has been steadily going forward and, as shown later in this report, is now in a much improved condition.[1]

TULARE.

The agitation that led to the formation of Tulare irrigation district goes back to the days preceding the passing of the Wright act in 1887. Several ditches had been taken out and were intermittently serving the territory about Tulare, but the people under them had not fared well and they made up their minds they could best improve their situation and circumscribe lower riparian proprietors through some community effort. For that reason they joined in bringing about the passage of the Wright act and the matter of organization was taken up shortly thereafter. At first it was planned to include all of the land south of Kaweah River between the foothills and Tulare Lake that was irrigable from that river, in all about 210,000 acres. This conception, however, soon proved too large, and after one landowner after another got himself eliminated the area of the district was finally cut down to 39,360 acres.

When Tulare district was organized not to exceed 3,500 acres, it is said, was being watered from Kaweah and Rocky Ford canals. Bonds to the amount of $500,000.00 were voted and $250,000.00 of these were used in the purchase of Settlers and Kaweah canals. After building a portion of the main canal from the proceeds of the $50,000.00 in bonds sold for cash, the district contracted for the construction of laterals and the enlargement and completion of the main canal, paying for the work indirectly in bonds. Thus, the district was able to get started in the delivery of water. All of this time, however, more and more friction was being developed and with the panic of 1893, when it was hard for farmers to get prices for anything, a number of attorneys employed by some of the larger landowners and by landowners in other districts with a view to breaking down all operation under the Wright act, began to arouse a feeling that the district had been illegally managed and that the bonds need never be paid. The district had originally organized by a vote of 484 to 7, and assessments had been regularly levied from 1890 to 1894 and paid without contest. In 1895, however, few paid district taxes, for "being hard pushed by the panic the consciences of the people were made a little easy." Returns from the crops being grown, it has been stated, would scarcely pay the

[1]No case involving Alta irrigation district is known to have been carried to the supreme court except one involving damages decided against the district in 1910 (*McPherson* vs. *Alta Irrigation District et al.*, 112 Pac. 193). In suits brought in the superior courts of both Tulare and Fresno counties property of the district necessary to the objects of the district was held not to be taxable by the counties. Many of the suits involving Alta irrigation district had to do with water rights on Kings River.

interest on the bonds, saying nothing of other taxes and living expenses.

While the sentiment for default was growing in Tulare district many of the substantial people held strongly together for keeping faith with the bondholders. As one has stated, "they had obtained the money in good faith, and had blown it in good faith, and were swamped in good faith, and should settle in good faith to the best of their ability." People holding that view, however, were in a minority and during the agitation and the panic property values within the district fell to almost nothing. For five years, it has been stated, "nobody nailed a board on a fence or planted a tree or a vine." In many instances crops were not planted, houses went into a state of dilapidation, and one bank and several mercantile establishments went out of business. While that state of affairs continued some water was kept running in the ditches, but the district itself practically ceased operating. At last it was realized that the only thing that could be done was to call the creditors together and offer to pay them as much as they could. After looking carefully into the situation those who were endeavoring to arrange a settlement decided that 50 cents on the dollar, not allowing anything for accrued interest, was about all the people could afford to pay.[1] This basis of settlement was accepted by the bondholders and $273,075.00 was raised in order to carry it out, some of the opposition holding out to the last hour during which opportunity for such a settlement was to remain open. On October 17, 1903, Tulare district bonds were burned and from that day the district has had no bonded indebtedness; for, unwilling after their long period of trouble, to be subject to further assessments, it was decided to operate the system on a purely tolls basis. With the exception of one assessment for betterments, the district has entirely maintained itself and operated its works out of water tolls since the compromise.

From the date of the compromise values in Tulare district immediately began to return to their former figure. District officers were again elected and the organization once more became active, and although now operating largely only as a cooperative company, as indicated later, has been active ever since.[2]

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[1]The present prosperity of farmers in Tulare district prompted a banker of Tulare recently to say that it is no credit to the people of the district that they settled at fifty cents on the dollar, for if they had postponed settlement a little longer they would have been able to pay the indebtedness in full. Looking at the situation as it was in the panic years of the nineties, however, he considers that they accomplished a task that was very much to their credit.

[2]Tulare irrigation district had more than its full share of litigation, some forty cases being on file in the superior court of Tulare County up to 1910. The organization of the district and the bonds were confirmed as early as April 2, 1890. Notwithstanding this, the superior court of Tulare County, in numerous suits seeking to have the bonds declared invalid and lands released from paying assessments, decided that the district had been illegally formed and that the bonds were invalid. No record has been found of decisions of the supreme court of the State on the legality of the district, but in the case of *Shepard* vs. *Tulare Irrigation District*, first carried to the federal courts in California (94 Fed. 1) and finally to the United

WALNUT.

Although not fully representative of the early irrigation district movement—it contains only 869¾ acres and has never taken advantage of the bonding provisions of the district law—Walnut irrigation district has the unique distinction of never having had financial trouble and of having been uninterruptedly successful from the beginning.

The district is located near Rivera, southwest of Whittier. For a number of years prior to organizing the community embraced had been receiving water somewhat irregularly from San Gabriel River through Standifer or Ranchito Ditch, but without rights to other than surplus water, and without adequate means for distributing what water they did get. Standifer Ditch was then unlined and losses from it were heavy, and it occurred to the small community near Rivera that if they could save the losses in that ditch above their lands and also in distributing water among themselves their supply would be satisfactory. They found that by organizing as an irrigation district they could condemn a right of way through Standifer Ditch and that they would also then have a convenient means of operating their irrigation system. Shortly after organization they brought a condemnation suit, probably friendly, against Standifer Water Ditch Association, also asking for the right to enlarge Standifer Ditch. In May, 1895, a settlement was agreed upon and entered as a court decree, awarding Walnut district the right to enlarge and use Standifer Ditch, provided that the district should build a wooden flume or otherwise improve the ditch and maintain it to a certain point in return for the double privilege of using the surplus water carried and of carrying the additional water the district should divert in accordance with a 200-inch filing from the San Gabriel made shortly after organization. The provisions of this decree were complied with by the district, the wooden flume extending from the Santa Fe track to the Pico or Whittier road, and costing approximately $6,000.00. Later this flume was taken out and the ditch cemented at a reported cost of about $8,000.00, which included the cost of a short section of cement pipe. The district also purchased a two-fifths interest in 17 acres of water-bearing land at the head of Standifer Ditch.

Walnut irrigation district was organized with practically unanimous consent and has definitely improved the conditions that existed prior to organization. Instead of issuing bonds, all funds have been raised by assessment or water tolls. While assessments during the reconstruction of the system were a little heavy, the operating expenses have been

States supreme court (185 U. S. 1), decided March 24, 1902, just a short time prior to the final settlement, it was held that *bona fide* purchasers of bonds occupied an unassailable position without regard either to the original judgment of confirmation or the later judgments declaring the districts invalid. In this case the district and the individual defendants relied only on the claim that there had been some defect in the printing of the original notice of the petition to the supervisors for organization.

exceptionally small and have been provided for by a charge of ten cents per hour per irrigating head used, the heads normally being about 200 inches. According to the agreement with the Standifer Ditch Company, the district pays all of the cost of maintaining from two to three miles of the ditch between the intake and the district line, and two-fifths of the remaining cost above the district. When assessments have been levied they have been voted practically unanimously and paid without delinquencies. The entire area in the district is irrigated.

In addition to the original condemnation suit, Walnut district has been involved in two suits that were taken to the supreme court, one of which,[1] was of importance. This suit had to do with the right of a landowner within the district to use outside of the district boundaries part of the water to which land owned by him within the district was entitled. The court held that under section 18 of the Wright act a landowner in an irrigation district had no right to water for use outside of the district, saying that "The right of a landowner of the district to the use of the water acquired by the district is a right to be exercised in consonance with and in furtherance of such ultimate purpose, viz., for the improvement by irrigation of lands within the district and in no other way."

Walnut irrigation district has been operated by a board of directors elected at large, although in practice selected to represent different divisions of the district. The district is chiefly devoted to walnut and citrus groves and is all irrigated. The present status of this district is described later.

ANAHEIM.

Anaheim irrigation district seems to have grown out of a rather general desire among the irrigators supplied by Anaheim Union Water Company to improve the water service of that company and to force the holders of the larger unirrigated tracts of the neighborhood to share the expense of the water development that was rapidly adding value to their lands. The district seems largely to have failed as a district because of being conceived on a too extensive scale, and because opposition that existed from the start was greater than it was possible to overcome. It strikingly illustrates, however, the great power of a minority to prevent the success of an irrigation district if determined to do so.

The history of Anaheim irrigation district is really the history of the critical period in the irrigation development of what is now one of the important agricultural communities of the state. Fortunately, that history, which is quite typical of the worthier but yet unsuccessful

[1] *Jenison* vs. *Redfield et al.*, 149 Cal. 500.

district organizations under the original Wright act, can be given largely in the words of one of the organizers and later presidents of the district, Mr. F. A. Korn, who, under date of September 15, 1900, when past 73 years of age, carefully penned an account of "irrigating thirty-three years in Orange County" in response to a request for information about the old district.

Omitting such portions of Mr. Korn's letter as can be omitted without breaking the story, he wrote as follows:

The undersigned bought in March, 1867, in the old colony of Anaheim. Anaheim irrigated at that time about 1,100 acres, mostly in grapes; water came from the Santa Ana River about three miles east of Anaheim. The water right was bought from the Yorba's (an old Spanish settlement) in 1857.

Shortly after I came to Anaheim the Stearns rancho was surveyed and put on the market. The first settlers arrived in 1869. It did not take long before they found out they could not raise a crop every year except they had water to irrigate with. A few settlers close to Anaheim applied for water to the Anaheim Water Company and it was sold to them for $3.00 per acre for one share of stock in the Anaheim Water Company. The other settlers on the northern side of Anaheim had to make their own ditches; it took several years before an irrigation ditch was made to the river. Even then it did not amount to much. It would not carry water in the summer months.

The legislature in 1872 (I believe) passed the so-called Bush act and under this act a number of farmers of Placentia had an irrigation ditch surveyed to Bedrock Canyon. They worked until their means were exhausted; it was about one-tenth part finished.

In 1875 or 1876 a gentleman bought a large tract west of Yorba and formed a company of all his neighbors and all those who had an interest in the unfinished ditch; this company was named the Cajon Canal Company. When in 1879 the Cajon Canal was finished, land which could be irrigated just doubled in value. In January, 1884, the Anaheim Water Company and the Cajon Canal Company consolidated and incorporated under the name of Anaheim Union Water Company with a capital of $1,200,000.00, divided into 12,000 shares, only 7,000 shares to be issued at present. The landowners had expected another rise in land values after a consolidation of the two water companies, but in this they were disappointed; a speculator would not improve his holdings knowing well enough they would bring big interest sooner or later. Time went along without much improvement, the Santa Fe railroad was built, the town of Fullerton came into existence, and the boom of this part of the country was felt all over. The Wright irrigation law had passed the legislature and several districts under this law had been formed in the northern part of the state. Many shareholders in the water company were dissatisfied, believing that under the Wright act irrigation water could be got cheaper than the Anaheim Union Water Company sold it although the company never charged more than the cost of running expenses. Many meetings were held, resulting in a petition to the board of supervisors to grant us the right to form an irrigation district. It took about one year before the board

of supervisors granted the right to form the Anaheim irrigation district; the land company and a few large landowners were against it. The first board of directors were elected and every farmer in the district believed the bonds would be sold before the end of the year, but they did not succeed.

When the next election was held I was elected director for the Anaheim district and was re-elected until the district was dissolved by the court. The board of directors under which I served did their best to sell bonds, but we never had an offer to sell our bonds for 90 cents on the dollar and for less than 90 cents we would not sell. A number of promoters and schemes made all kinds of propositions but we wanted to see cash to build reservoirs with.

Nearly four years had passed with us not being able to sell any bonds and $36,000.00 had so far uselessly been expended. The taxpayers began to think they had expended money enough to form an irrigation district. An election was held to dissolve the district which was almost unanimously carried. All our debts were paid, and the superior court dissolved the district.

Other data than are included in the above letter indicate that the controversy over the organization of Anaheim district was at times heated, and that some of the ablest lawyers of southern California were arrayed on the opposing sides. It had been proposed to purchase the system of the Anaheim Union Water Company for $300,000.00 in bonds and to pay $40,000.00 in bonds for the rights of the Yorba irrigators. While those in control of the Anaheim Union Water Company had acquiesced in the sale of their system, a number of the larger shareholders and the irrigators at Yorba strongly objected to relinquishing to the district their water rights acquired about 1858 for fear that the water was to be spread over a too large area. A bond issue of $600,000.00 was, however, carried, but while the directors were considering and were about to consummate its sale, feeling became more bitter and the opposition redoubled their efforts, charging the directors with inefficiency and inability to handle so much money, and claiming that the bonds would be sold at a heavy loss, and the section irretrievably ruined. Taxpayers in the city of Anaheim, which was included in the district, joined with the opposition. Finally, some of those who had been active in favor of the district went over to the opposition and the long fight was given up.[1] The district was dissolved by the superior court of Orange County September 12, 1895.

[1]The area served by Anaheim Union Water Company, which is a mutual company, is now in a highly prosperous condition. Investigations of the use of water from Santa Ana River in 1912 showed a total of 13,000 acres being irrigated by this company, with a supplemental supply being provided to 5,245 acres from private wells. All of the land included in the old irrigation district has not, however, been watered. While during its formative period the district enterprise greatly inflated land prices, and in that way caused some heavy losses, the efforts to form it probably had as their chief result a valuable addition to the experience of the irrigators about Anaheim in managing their own irrigation affairs.

DISTRICTS ESSENTIALLY SPECULATIVE.

For the first three years after the passage of the Wright act no one used it as a cloak to cover up speculation. On the contrary, while many of the districts started during those years undoubtedly should never have been started, and regardless of the undue optimism of their organizers, there is ample indication that the purpose prompting their formation was essentially a *bona fide* and constructive one. To those who recall the frenzied wave of land speculation, especially in southern California, that culminated during the early nineties, it is not at all surprising that the Wright act should have been made use of as an agency in that speculation. The spirit and purpose of the act plainly limited its use to existing communities desiring, over the objections of an obstructing minority, to use the taxing power and the power of eminent domain to obtain or improve an irrigation water supply. Not being framed to cover purely speculative enterprises, no safeguards against its misuse were thrown around it, and it readily became an easy tool in the hands of manipulators. It is of no particular consequence at this time whether those who misused this law were honest or dishonest, nor will anything be gained at this time by criticizing their ethics. The period was a hopeful one and in the confidence men felt in the future some things were done that probably seemed proper then but which would not be countenanced now. So far as concerns some of the districts classed as essentially speculative, that is probably the most that can be said, and as to some even that probably is not justified. However, whatever of value is to come from a history of these old enterprises must come from a plain recital of how they operated and by what means they brought discredit on the law and disaster whose effects are in some cases still felt to the communities they embraced.

The Wright Act was written to make it possible for a reasonable number of landowners in any community to bring to an issue the question of whether a means of irrigation should be provided, in spite of the opposition of large landowners who were content to farm their large holdings on a margin of profit per acre that would be prohibitive to the smaller farmers. So it was provided that "fifty, or a majority of the holders of title, or evidence of title," might propose the organization of an irrigation district. Fifty or a majority in a section already under cultivation was quite sure to represent a substantial interest, but fifty or a majority of dummy entrymen or purchasers, or even of *bona fide* entrymen or purchasers in a desert country brought in or "colonized" merely to make possible the initiation of an irrigation district, might represent no substantial interest whatever. So also two-thirds of all of the electors in a section already under cultivation, when called upon to decide as to organization, or a majority, when called

upon to authorize a bond issue, were likely to stand for an interest sufficiently large to justify going ahead or trying to do so. On the other hand, two-thirds or even a majority of the electors in a "colonized" desert section were quite sure to represent but a very small percentage of the ultimate settlers who must pay the principal portion of any bonded indebtedness incurred.

Of the eleven districts classed as essentially speculative only Big Rock Creek and Little Rock Creek are now active, the former having been revived in 1914 and the latter about 1910. The present status of these two districts is described in connection with active districts but an outline of their early history and failure and of the history and failure of the other nine are briefly given below.

SUNSET.

The guiding spirit of this district was a promoter, aided by a group of people in Fresno and Selma. Its chief historical interest lies in what may charitably be looked upon as an approach to the grotesque.

Sunset irrigation district covered a strip of desert from one to twelve miles wide and about seventy miles long, extending from near Mendota to Tulare Lake. Although a few had attempted from time to time to establish homes there, the land included was almost wholly owned by nonresidents, with alternate sections railroad land. To accomplish organization a quarter section was subdivided into small lots and either given away or sold at nominal prices to those who would agree to vote for organization. Probably it was also prearranged that bonds should be voted, for a $2,000,000.00 issue was easily carried within three months of organization.[1] In general the scheme proposed by the promoters was to take water from Kings River by way of Summit Lake, irrigating 87,000 acres by gravity and 178,000 by pumping from Fresno Slough by means of seventeen 44-inch centrifugal pumps raising water through four 11-foot lifts. Cereals, it was stated, would never need but one flooding and six inches added to the natural rainfall would be ample. Grasses were to be served three times with four inches in depth at each wetting, "one foot to each 250 acres of land." The system was to include 500 miles of earthen channels and utilize 3,000,000 feet of lumber, and the gross water duty was figured at one acre-foot per acre. Unfortunately the engineer did not specify how he was to take care of seepage losses. Nevertheless, he was paid $20,000.00 in bonds for his services. He should have been satisfied, however, for only $300,000.00 in bonds was paid for rights of way and reservoirs and

[1] It is quite evident from the record of the district that the plans of the system and its cost were worked out to the satisfaction of the promoters before the enterprise was started and it was apparently their desire to call for a bond issue at once. However, their attorney advised the directors at their first meeting "that it would not look right to order an election on bonds at the first meeting of the board," and accordingly this formality was postponed for two months.

"water rights" on Kings River calling for 3,000 cubic feet per second after previous claims were satisfied, but with the title to any of the 3,000 cubic feet per second apparently never having been perfected either by use or court decree.[1]

In the heyday of its hope the directors of Sunset irrigation district were in no wise modest regarding the virtues of their enterprise. In an undated printed prospectus issued some time after October, 1896, (the last date mentioned in the prospectus) some quite elaborate and variegated penwriting was resorted to in describing the results of irrigation at Riverside, "but" adds the prospectus, "with all its grandeur, Riverside can not compare in soil, climate, or any of nature's gifts, with Sunset."

Even after a lapse of nearly twenty-five years, and also even granting that many, acting in entire good faith, were prompted through misinformation or absence of information to attempt the impossible under the Wright act, it is difficult to look with patience on the operations of those who promoted and managed this district. Even as early as February, 1892, a prominent San Francisco bank had characterized Sunset district as a fraud. The most cursory public supervision, it would seem, should have prevented this district from ever being formed, saying nothing of the operations subsequent to organization.[2]

MANZANA, LITTLE ROCK CREEK, AND BIG ROCK CREEK.

In the activity under the Wright act, Mojave Desert, or Antelope Valley, was not overlooked. Of six districts formed there between 1890 and 1895, Manzana, Little Rock Creek, and Big Rock Creek have been

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[1]The record of the district indicates that quite early in its history some doubt arose as to the legality of the organization procedure that was followed. When the district was organized, as already stated, a tract within the district was subdivided and the parcels thereof sold or given away to those who would agree to help carry the election on the organization. On October 24, 1891, the attorney for the district wrote to the promoter in a much disturbed state of mind over the fact that some one connected with the district had expressed his doubts about the "freeholder proposition," meaning the colonization of "freeholders" to carry the election. "If it should come to the ears of the judge," the attorney stated, "he might feel called upon to institute an inquiry when otherwise a decree (of confirmation) would certainly be entered on the record showing." Evidently the promoter and the attorney resolved all doubts in favor of the district, for they were able to satisfy the superior court with the evidence presented and to secure a decree of confirmation. This decree, however, might well have been based on safer grounds, for when, after paying assessments for several years and seeing nothing accomplished, and after seeing interest on outstanding bonds defaulted, the nonresident landowners and the bondholders took the matter in hand, they had no difficulty in getting the decree set aside as a fraud on the court and the district declared null and void.

[2]On several occasions the board issued warrants to pay the interest on some of the bonds that had been disposed of, but in September, 1893, the directors decided that it was not advisable to levy an assessment to pay interest on bonds. The directors subsequently obtained an opinion from their attorney on the matter, which held that there was no doubt as to the meaning of the law, which required an annual levy to pay interest where there were outstanding bonds. "In the case of Sunset district, however," the attorney stated, "it seems to me it must have been apparent to those who took bonds of the district that the district would be unable to pay until the water should be applied to the lands. If such was the case they will, of course, feel no disappointment if accrued interest be not provided for until the water has been applied to the lands."

classed as speculative, for they were all promoted by companies or individuals desiring to sell land and who either were misled by the extranormal water supply in sight during the late eighties, or took advantage of the unusual conditions of those years to consummate their plans. In each case "colonization" was necessary before a district could be organized, and in each water rights held by the promoters or acquired by them for the purpose were traded for district bonds. In each case, after considerable areas of land had been sold to nonresidents and in many instances planted to orchards, the water supply failed as the dry years of the nineties came on, and with this condition there was in each case a default in payment of taxes and in the meeting of bond interest and finally an exodus of the settlers. Manzana district disposed of about $40,000.00 worth of bonds, Little Rock Creek about $88,000.00, and Big Rock Creek in excess of $223,000.00. The water supply in Manzana district which purported to be sufficient for 3,000 acres dwindled in the dry years until there was sufficient only for domestic use on a few farms. Big Rock Creek district covered about 30,000 acres and the several hundred people said at one time to have resided in the district were reduced by the drouth to a very few, irrigating only about 100 acres. In Little Rock district the area embraced was 4,100 acres, including about 1,300 acres of unpatented land. By installing a pumping plant near the intake of the district ditch the people of this district were able to tide over the dry years with a water supply apparently somewhat below 100 inches. Almonds largely made up the orchard crop planted in all three of these districts, and as a rule the land had been planted by the promoting companies and sold to eastern buyers who had never seen the land, with agreements to maintain the orchards for a stated number of years.

Manzana district has never been rehabilitated and its bonded indebtedness is still unsettled, with no plan of settlement in view, and with but a very small acreage now irrigated. In Big Rock Creek district a second effort was made to colonize the area by an eastern colonization company which had acquired a considerable area in the district and which is said to have taken some part in supporting the original colonization movement. In consideration of receiving additional district bonds, estimated at from $30,000.00 to $50,000.00 par value, this second company undertook to increase the water supply by driving a tunnel 2,600 feet into the bed of Rock Creek. Here again, however, failure was met, for only a small quantity of water was obtained and the settlers whom this second colonization movement had brought in also abandoned their holdings and moved away. A third effort to occupy the district was made in 1914 when a group of Los Angeles socialists began the establishment of a socialist colony there. The present status of this movement is given elsewhere. By getting the supervisors of Los Angeles

County to appoint a new board of directors for the district those back of the present movement were able to resuscitate the old organization. February 3, 1915, a new board was elected by the people. The present promoting company has acquired about $60,000.00 par value of the old bonds and has located an additional amount of $65,000.00, and suits are now pending in the Los Angeles County superior court to obtain judgments on some or all of the bonds. Little Rock Creek district has also recently been rehabilitated. About ten years ago the few settlers who remained after the exodus of the nineties formed a mutual water company and undertook to acquire the old district works and in this connection petitioned the court for dissolution of the district. Being objected to by some of the bondholders, however, this plan was abandoned and a movement started to revive the district. An agreement was made with the bondholders by which the $88,000.00 of bonds that had been issued should be funded with $25,000.00 of new bonds, and in September, 1910, new bonds for the purpose were voted and also bonds to the amount of $35,000.00 which it had been stipulated should be used in improving the irrigation system. What has been done under this compromise and what has been accomplished in the way of agricultural development of the district are both told later in this report.

PERRIS AND ALESSANDRO.

The first to be formed of the Wright districts classed in this report as essentially speculative was Perris, which dates from June 2, 1890. About six months later it was followed by Alessandro district. These two districts strikingly illustrate some of the worst features of activity under the Wright act. The history of both of them is closely interwoven with the history of the various companies that were organized to exploit Bear Valley reservoir. Both seem to have been operated on the theory that the purpose in view justified any means necessary to accomplish it. Both passed through brief but stormy careers and both ceased activity with the failure of their supposed water supplies. Finally, twenty years after they ceased activity, their bonded indebtedness has been disposed of, in the one case by having judgments amounting to $567,300.00 compromised at about 40 cents on the dollar, and in the other case by being held uncollectible because the bondholders had had notice in the printed prospectus of the district that the bonds were delivered to Bear Valley Irrigation Company "not for water, but for an executory contract to deliver water in the future."

Prior to the organization of Perris district land about Perris was mostly in small holdings and to a considerable extent was being hazardously dry-farmed to wheat and barley. The organization election was carried by 81 to 2, as was a bond issue of $442,000.00 shortly thereafter by 69 to 1. Later it was found that of 59 signing the petition for the

formation of the district, only eight were bona fide freeholders. At the time of organization no one had any clear notion as to where a water supply could be obtained, but every one was optimistic. Soon attention was centered on Bear Valley reservoir, some believing that the promoters of Bear Valley reservoir had instigated the formation of the district in order to get its bonds for development purposes, as was the case with Alessandro district. At any rate, when visiting Bear Valley dam and "while standing on that magnificent piece of masonry" it was agreed that that "gigantic reservoir" furnished "the safest, best, and most feasible system of water supply yet examined," and that if it could be had at satisfactory cost, "their land should have no other." On January 20, 1891, the district contracted with Bear Valley Irrigation Company for the exchange of $240,000.00 in bonds for "Class B" water rights in Bear Valley reservoir. About the same time they began the construction of a conduit to the district and a distributing system, the entire works of the district being then estimated to cost $710,000.00. By the exchange of bonds for material and labor, by the issuance of warrants and their later redemption in bonds, and by purchasing a portion of the pipe system as "real estate" after it had been laid, some $200,000.00 in bonds was expended on construction work and one main pipe-line and distributing mains in the district were built. As a result of this activity water was delivered for a year or two by Bear Valley Irrigation Company, when the dry years of the early nineties came on. Then, however, the "Class B" rights for which the district had exchanged $240,000.00 in bonds turned out to be paper rights only, for all of the water supplied by Bear Valley reservoir was insufficient even for the holders of "Class A" rights about Redlands, Crafton, and Lugonia, and for reasons given more fully in connection with Alessandro district, Bear Valley Irrigation Company passed into the hands of a receiver. Orchards that were just getting nicely started died and the optimism that had thus far carried the organization along now turned into an intense depression. Many abandoned their holdings and at least twenty houses, it is said, were moved to Riverside. With the failure of Bear Valley Irrigation Company all hope of saving Perris district was abandoned.

The gradually increasing strife among the proponents and the opponents of Perris district furnishes one of the most interesting phases of the history of early California irrigation districts, and also indicates the utter futility of attempting to carry through an irrigation district in a community bitterly divided against itself. Only a few cool heads, it is stated, at one period prevented bodily encounter; one threat to kill on sight is mentioned in the data that have been gathered. Each side grasped at the slightest chance to check or discredit the other. The opposing group, forty or fifty strong, organized a branch of the Knights

of Labor and held weekly meetings in the seclusion of the neighboring foothills. In this step they were met by the formation of the "Patterson Guards," made up of about an equal number who were supporting the district. Each organization is said to have been on a military footing with every member armed. Suit was brought to oust one member of the board of directors of the district on the charge that certain of his acts were illegal. He was arrested, but was surreptitiously tried, it is stated, by a friendly justice sitting at a "haymow" trial, and acquitted. On one occasion some of the "antis" had the entire board arrested and taken to San Diego for trial. A charge against the proponents of the district, alleged in a later suit, involved bribing the lawyer hired by the "antis" to fight confirmation proceedings to stay away from the trial. Finally, a source of bitter contention was the control of the local newspaper. At the start it was in the hands of those promoting the district, but the editor later went over to the other side, as did also the ownership, and from that time on bitterly attacked those in control. On one occasion the editor and proprietor of this paper and one of the "anti" directors had the pleasure of having themselves burned in effigy.

Alessandro district was even more closely identified with the Bear Valley Irrigation Company and its predecessors than was Perris. The original company, known as the Bear Valley Land and Water Company, was organized in 1883. This company first constructed Bear Valley dam at a reported cost of $75,000.00 and sold first rights to the water impounded to the landowners about Crafton, Lugonia, and Redlands.

In 1890 the Bear Valley and Alessandro Development Company was formed and it acquired a majority of stock of the first company, and also about 21,000 acres of land about Alessandro and Moreno, in San Jacinto Valley, which it proposed to supply with water by constructing a second dam in Bear Valley about 200 feet below the first dam, this new structure to increase the capacity of the reservoir to 80,000 acre-feet. In order to finish this larger project the development company promoted Alessandro irrigation district, all of the organization expenses of which it paid and which it dominated from the first. According to a prearranged plan the district forthwith voted bonds to the amount of $765,000.00, which it turned over to a second new company, known as Bear Valley Irrigation Company, which in the meantime had taken over the two former companies. In consideration of the $765,000.00 bonds of the district, Bear Valley Irrigation Company issued to the district more "Class B" water-right certificates and contracted to enlarge Bear Valley reservoir as previously indicated and to build conduits to and through the district, both the reservoir and the conduits, however, to remain the property of the selling company. All distributing works other than the main conduits were to be built by the landowners. According to allegations in one of the suits later brought

against the district, three-fourths of the petitioners for the formation of the district, including two of those subsequently elected to the first board of directors, were employees of the selling company, and the engineer of that company was also made the engineer of the district. Thus, in return for $765,000.00 in bonds, most of which were disposed of in England and Scotland—some at a premium—the district obtained merely the "right" to receive water from works as yet unfinished, and as to the sufficiency of which there were no substantial data available, although the principal consulting engineer employed reported in a highly optimistic printed prospectus that the company could and would fulfill its contract to supply the district.

Apparently Bear Valley Irrigation Company started out with a show of keeping its agreement, but if data that have been collected and allegations in various suits can be depended upon as correct, much of the money ($130,000.00, July 1, 1891, $209,350.00 in 1893, and other amounts not mentioned in the records at hand) obtained from bonds and from other sources was used in paying dividends instead of for construction, although Bear Valley Irrigation Company had laid the foundation for the proposed new Bear Valley dam in a substantial manner in 1893, and had also built a conduit to the district carrying something less than 1,000 inches. By December, 1893, however, Bear Valley Irrigation Company was completely wrecked and passed into the hands of a receiver, together with all of its promises, and the district found itself with absolutely nothing for its pains and its $765,000.00 in bonds. For a few years the district had collected district taxes and paid bond interest, but with the failure of the promoting company and its prior default in carrying out its contract, payment of both taxes and interest ceased. For a few years the receiver operated the portion of the system that had been built, but the dry years, beginning in 1895, demonstrated that the water supply was wholly inadequate, and that the "Class B" water-right certificates were but "mere phantoms" and represented nothing more than the vision of the promoters. After the utter failure of the water supply land prices that had risen from $10.00 an acre to $125.00 dropped to practically nothing, and nearly all of the five hundred families said at one time to have lived in the district moved away. If we can accept the view of one thoroughly familiar with the early history of Alessandro district "there probably never was a place that suffered as that did."[1]

[1]Perris district has been involved in much interesting litigation. In early days the organization of the district and its bond issues were confirmed in various suits, although it was later claimed that fraud had been practiced in one of them. In *quo warranto* proceedings started in 1897 the district was declared illegally organized and its rights forfeited, but this decision was reversed by the supreme court (*People* vs. *Perris Irrigation District*, 132 Cal. 289). In a later supreme court case (*Leeman* vs. *Perris Irrigation District*, 140 Cal. 540) it was held that no action can lie on bonds given for warrants in payment of labor and salary claims when the bondholder knew that the statute was being violated in the disposal of the bonds. Suits to collect from the district have mainly been brought in the United States

RIALTO AND CITRUS BELT.

These two districts, like Perris and Alessandro, were twin promotion schemes, being organized in October and November, 1890. The enterprise back of them was the Semi-Tropic Land and Water Company. The 20,000 acres embraced in the two districts were purchased by that company at a low figure—the market price at the time in small holdings was about $25.00 per acre—and was to be sold at $175.00 and $200.00 per acre after a water supply should have been provided through the organization of the two irrigation districts. By selling off a number of small holdings enough voters were got in to organize the districts and to vote bonds—$500,000.00 in Rialto, and $800,000.00 in Citrus Belt. Thereupon the company obtained agreements by which it should furnish water to the districts at the rate of about one inch to each seven and one-half acres. Work on the Rialto system was started at once and after a number of years of effort about two-thirds of the total water supply contracted for was developed and a considerable portion of the distributing system built. By the spring of 1894, however, the narrow margin of working capital on which the promoting company had attempted to operate forced it into the hands of a receiver. This crisis

courts. In a case carried to the circuit court of appeals (*Board of Supervisors et al.* vs. *Thompson et al.*, 122 Fed. 860) a judgment directing the issuance of a peremptory writ of *mandamus* to compel the supervisors of Riverside County to levy an assessment as provided in section 39 of the irrigation act of 1897 to pay a judgment against the district was affirmed but no collections were made under that decision. (Other federal cases involving Perris district bonds were *Miller* vs. *Perris Irrigation District*, 85 Fed. 693; *Miller* vs. *Perris Irrigation District*, 92 Fed. 263; *Miller* vs. *Perris Irrigation District*, 99 Fed. 143; *Thompson* vs. *Perris Irrigation District*, 116 Fed. 769, and *Perris Irrigation District* vs. *Thompson*, 116 Fed. 832.) In 1913 section 39 of the act of 1897 was amended to make it the duty of district attorneys to act in case of the failure of boards of directors to levy assessments required by law to be levied, and the amendment was held valid by the superior court of Riverside County on April 2, 1914, and the supervisors were ordered to levy an assessment against the lands of the district to pay numerous judgments then outstanding. In October, 1914, and again in March, 1915, levies were made by the supervisors of Riverside County to pay judgments aggregating about $455,000. These assessments, however, were made pursuant to a compromise with the bondholders by which judgments aggregating $569,300 were settled for about forty cents on the dollar, and July 2, 1915, was set as the day for burning the bonds the above judgments covered.

Alessandro district was also in litigation throughout its existence and even down to 1913, more than thirty cases involving it being of record. The organization of the district and the bond issue were first confirmed and later declared illegal on account of irregularity, the supreme court in deciding this latter question holding that the board of directors had "no power to give all the bonds of the district for a mere personal promise of another that it will in the future lease some water to the district at a stipulated rent." (*Stimson* vs. *Alessandro Irrigation District*, 135 Cal. 389.) In 1905 what purported to be dissolution proceedings were carried through in the superior court of Riverside County without notice to the bondholders. On learning of the purported dissolution, however, bondholders representing claims aggregating $600,000 brought suit to have the decree of dissolution set aside and for judgment on their claims. The decision in this suit, entered in January, 1913, finally resulted in wiping out the entire bonded indebtedness. Not only did it throw out the dissolution judgment of 1905 as "void and a fraud on the court," but it declared the bondholders could not collect because, as previously indicated, they had had notice in the printed prospectus of the district that the bonds were delivered to Bear Valley Irrigation Company "not for water but for an executory contract to deliver water in the future." The confirmation judgment of 1891 was held void "for want of jurisdiction," and the judgment in the *quo warranto* proceedings of November 18, 1898, was declared valid and held to have terminated the existence of the district. With this judgment future action by the bondholders was dropped and the bonds have since been burned.

terminated all effort to carry out the contract with Citrus Belt district and the bonds of that district, previously trusteed, were returned to the district and the district subsequently disorganized after paying off its outstanding warrants at 50 cents on the dollar. The agreement with Rialto district, however, was assigned to the promoting company's contractor, and he continued work on the system, in all laying about seventy-five miles of pipe. Up to this time and for another year the district continued to levy assessments and to pay bond interest, but in 1895, when the dry period came on and the artesian wells that had been sunk ceased to flow, the people became discouraged and refused longer to pay their district taxes. Many of the orchards began to die and to save themselves those using water formed the Citizens Mutual Water Company and by boring additional wells and installing pumping machinery, developed sufficient water gradually to develop a prosperous community around Bloomington, the mutual water company continuing the use of the district distributing system. Later the Citizens Water Company was reorganized under the name of Citizens Land and Water Company, which is still operating the system. In the meantime, although inactive, the district has maintained its organization. The old bonds of the district, however, of which about $411,000.00 were issued, have not yet been settled, although heavy judgments have recently been given in the United States district court, and the collection of these and suits covering additional claims are still pending.[1] The Citizens Land and Water Company gathered up about one-half of the old bonds at reported prices ranging from 12 to 25 cents on the dollar, and offered in 1909 to assume the remaining outstanding indebtedness, then amounting to $260,000.00, on condition that all of the property of the district should be deeded to the company and the district disorganized, this proposal having been made after agreement and conference with the bondholders. When the proposition was submitted to the electors of the district, however, in 1910, it failed of approval by a vote of 54 to 71.[2]

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[1]Following the judgment referred to, Rialto district obtained the passage by the legislature of 1915 of an amendment to section 39 of the irrigation district act, the amendment providing "that in any district organized prior to 1891 the amount to be levied for the purpose of paying any judgment or judgments, shall not exceed the sum of $25,000 in any one year * * * ." Other similar attempts have been made to legalize what would have very strongly suggested repudiation, but the amendment submitted by Rialto district was the first one to pass the legislature. This amendment, however, did not receive executive approval. In judging of these efforts to obtain legislation that would lessen the burden of the landowner on account of the old district bonds, it should perhaps be remembered that the present landowners are not the ones who organized the district, and that present bondholders probably obtained the bonds as a speculation at a very low figure.

[2]Citrus Belt district was involved in no litigation of consequence, it having been saved that trouble by the wise advice of its attorneys that bonds could not be exchanged for work. Conditions have been quite different, however, in Rialto district. In an early case (*Rialto Irrigating District* vs. *J. R. Brandon et al.*, 103 Cal. 384) it was held that the provisions of the Wright act referring to the construction of "ditches and canals" and giving a district power to condemn property necessary for works were broad enough to include pipe lines, flumes, or other conduits

MURRIETTA, LINDA VISTA, AND JAMACHA.

These three districts were formed in 1890 and 1891, the years of greatest activity in organizing under the Wright act. Murrietta district, then in San Diego County, although embracing 14,000 acres, was unimportant and accomplished nothing beyond sinking a single artesian well, and without voting any bonds, or incurring indebtedness, that could not readily be paid, ceased activity and was dissolved. It had been formed, in the first place, by a local land company that had acquired some 2,200 acres for subdivisional purposes. Jamacha district, originally promoted as Spring Valley district, was more feasible and if properly managed could have succeeded for at least a part of the area included. This district was promoted by the owner of certain properties it was desired to sell to the district and by the owners of land who hoped to reap a profit in subdividing their holdings. The water supply disposed of to the district included the Barrett damsite, at which point water from Cottonwood and Pine creeks was to be impounded. These properties were purchased for $100,000.00 in bonds which were a part of a $700,000.00 issue that had been voted. An adverse bank report stopped the disposal of any further bonds, but at this juncture the properties that had been acquired were taken over by the Southern California Mountain Water Company and the bonds traded for them returned to the district. The district was finally dissolved May 5, 1909.

Linda Vista district, covering 42,600 acres on Linda Vista mesa north of San Diego, was similar in some respects to Jamacha district and was promoted somewhat in the same way—that is, those behind it were chiefly holders of mountain storage and appropriation rights and those who wished to increase their profits in real estate. In the general ignorance of irrigation matters common to the time, some outsiders rushed in in entire good faith, expecting to make quick fortunes. Their illusion, however, was not long-lived, for the financial plans of this district failed along with those of others, and no bonds were disposed of other than those traded to the promoters for filings on Pamo Creek and Santa Ysabel River, a storage site in Pamo Valley, and small areas and rights in Santa Maria and Dye valleys, in all $176,000.00. These old bonds hung over the district for twenty years, but were finally disposed of and the district dissolved April 15, 1914. During

usually employed in works of the kind for conveying water. In a lower court case in *Stowell* vs. *Rialto Irrigation District*, bonds received by the contractor from the Semi-Tropic Land and Water Company were held invalid on authority of previous supreme court decisions (*Hughson* vs. *Crane*, 115 Cal. 404; *Stimson* vs. *Alessandro Irrigation District*, 135 Cal. 389, and *Leeman* vs. *Perris Irrigation District*, 140 Cal. 540) because the contract of the company provided that bonds of the district were to be issued in part at least for construction work. On appeal, however (155 Cal. 215), this decision was reversed, the court saying in effect that where a district enters into a contract for the transfer to it at different times of specific water rights with completed pipe lines and rights of way, to be paid for in bonds to be issued only on delivery of a deed conveying the property, the bonds are valid.

the interval, litigation had reduced all of the district's debts to judgments, all of which were acquired by a local corporation. This corporation returned $55,000.00 of the old bonds in exchange for the water properties purchased by the district twenty years previously for $176,000.00 in bonds, the remaining indebtedness being compromised for a total of $125,000.00 that was raised by assessment.[1]

Conceived in speculation, although honestly supported by many; far in advance of a legitimate demand for the development it would make possible, bitterly opposed by the owners of some of the larger holdings embraced, based on too meager water supply and cost data in those early days of western irrigation engineering, ill-timed and managed by men either inexperienced in large affairs or not disinterested, Linda Vista district tested the weaknesses rather than the constructive possibilities of the act under which it was created. Even with a water supply unquestioned and certain it would have been too large an undertaking to be economically and successfully carried through by nonresident landholders mostly waiting for a chance to sell out. That it failed when it did is without doubt to someone's great advantage.

THE IRRIGATION DISTRICT ACT OF 1897.

By the close of the first decade of operation under the Wright act the necessity for a radical revision of that act was fully apparent. The numerous amendments and supplemental acts that from time to time had been adopted had been drafted more with a view to meeting local needs of particular districts or to clearing up doubtful provisions, than to correcting abuses. The abandonment or complete collapse of all but six of the forty-nine districts organized, and the critical financial difficulties of all but one of those six, so discredited irrigation districts and the securities they were dependent on that friends of the district movement, particularly those connected with the few districts for which there was still some hope, in 1897 set about rewriting the original act in such manner as to make a repetition of previous disasters impossible. The Wright act had not failed because of what it contained so much as because of what it did not contain. In a time of less speculation and of less financial stress it could have well sufficed in those situations that had inspired it and to meet which it had been drafted. With complications arising from the speculative districts and from the financial panic of the nineties eliminated, such districts as Modesto, Turlock,

[1]Linda Vista District was involved in litigation from the start, including obstruction suits, suits to enjoin tax sales, a suit by the city of San Diego to be relieved from district taxes (first decided in favor of the city, but reversed by the supreme court in *San Diego* vs. *Linda Vista Irrigation District*, 108 Cal. 189), suits to enforce the payment of bond coupons and warrants, an individual suit to dissolve the district, and *quo warranto* proceedings to set aside the district organization, the latter being decided in favor of the district both in the superior court and in the supreme court in *People* vs. *Linda Vista Irrigation District*, 128 Cal. 477.

Madera (on a smaller scale), Alta, Tulare, Happy Valley, and Browns Valley, in Sacramento and San Joaquin valleys, and a few in southern California would have succeeded without great difficulty, for the bringing in of water would gradually have broken down local opposition. The time had not come, however, when communities unused to working together or to the management of large affairs could withstand both the critical industrial conditions of the nineties and the bitter onslaughts that were made on the basic act under which they were attempting to operate. The decision of the United States supreme court sustaining the constitutionality of the Wright act,[1] following a decision in the lower federal court holding the act unconstitutional,[2] was delivered November 16, 1896, after previous argument by some of the foremost lawyers of the times, including a former president. Thus, those who went to the legislature of 1897 with a redraft of the act did so with knowledge that its fundamental principle was at last unassailable.

The essential character of the Wright act was not affected by the amendments of 1897. While the original act was repealed, the new act was in many of its provisions but a slight verbal revision of the old one, with the three separate confirmation, inclusion, and exclusion acts of 1889 added. Radical changes were, however, made in the procedure for organization and for incurring indebtedness. Instead of giving to fifty or a majority of the landowners in any proposed district the right to initiate such district before the supervisors, the amended act required "a majority in number of the holders of title or evidence of title to lands susceptible of irrigation from a common source and by the same system of works, representing a majority in value of the lands," and for the former provisions permitting the boards of directors to call bond elections and to acquire water rights and works and other property necessary therefor without restriction, the amended act prescribed that a petition signed by a majority of the landowners, representing a majority in value of the lands, should precede the calling of any bond election and any purchase of works or other real property at a price exceeding $10,000.00.[3]

[1] *Fallbrook Irrigation District* vs. *Bradley*, 164 U. S. 112.
[2] *Bradley et al.* vs. *Fallbrook Irrigation District et al.*, 68 Fed. 948.
[3] Among the more important of the other new features in the act of 1897 were the following: Provision for right of appeal to superior court on order of supervisors on organization petition; provision for contest of election on organization; provisions for consolidation, where desirable, of certain offices and for fixing by boards of directors of bonds of treasurer and collector; provision for annual financial statements; provision that directors need not reside in division from which elected; provision that assessments to complete works when there should be no money in the construction fund and no bonds should be voted could only be levied after first having been approved by a majority vote of the electors; exemption of district property from state and county or municipal taxes; provision that bonds should bear five instead of six per cent, that they could not be sold below par, and that they should be paid from the twenty-first to the thirtieth years instead of from the eleventh to the twentieth. In addition, the act of 1897 omitted, among other things, the former provision that district bonds could be used at their par value in payment for lands, water rights, etc.

IRRIGATION DISTRICT LEGISLATION SINCE THE ACT OF 1897.

Attention has already been called to the revision of the Wright act of 1887 that was embodied in the act of 1897. The restrictions imposed by the amended act on the organization of irrigation districts and on the incurring of indebtedness by boards of directors were planned virtually to stop new development under the law, and for more than ten years that was their effect. The legislature that substituted the amended law for the original Wright act also passed what is known as the funding act[1] under which irrigation districts were permitted to discharge their indebtedness with new bonds.[2] For the next four years the law was left unaltered, but beginning in 1901 and more particularly in 1909, 1911, 1913, and 1915, amendments and supplementary acts were adopted that have greatly changed and strengthened it, and while it is not yet in the final form desired by some of its friends it stands in many particulars as tested, workable, and satisfactory. Many of the changes that have been made have dealt mainly with matters of routine and detail. Some have been intended to meet the needs in individual districts. The more important of the changes of general application are summarized below.

BONDS.

The first amending act affecting bonds was passed in 1901[3] and related only to the funding act of 1897. This act amended three sections of the funding act and repealed six sections. Thereafter no legislation was enacted affecting bonds until 1911, when the first statute was passed providing for investigation and report on bonding issues by a state commission, composed of the attorney general, the state engineer, and the superintendent of banks. This initial act did not prove satisfactory and it was superseded a few months later by a new act,[4] but this in turn was superseded in 1913,[5] and was slightly amended in 1915.[6] The enactment of 1913 as amended in 1915 is now in force. In general it provides that on application from an irrigation district the state irrigation commission, composed of the attorney general, the state engineer, and the superintendent of banks shall investigate and report on essential matters having to do with the water

[1]Statutes 1897, chapter CCLIV, p. 394.
[2]Under this act Modesto, Turlock, and Alta districts, and some years later, Little Rock Creek district, refunded their old indebtedness and otherwise reorganized. (*See* histories of these districts in text.)
[3]Statutes 1901, chapter CLIX, p. 514.
[4]Statutes 1911 (extra session), chapter III, p. 3.
[5]Statutes 1913, chapter 366, p. 788.
[6]Statutes 1915, chapter 419.

supply of such district, the fertility and irrigability of its soil, the feasibility of its irrigation system, the market value of its water rights and works, the market value of the lands embraced, as to whether the aggregate amount of the authorized bonds outstanding or unsold exceeds 60 per cent of the aggregate value of lands, waterworks, etc., owned or to be built or acquired, and as to the number and amount of bonds available for the purposes of the act or that may be available. If the report of the commission is favorable the law provides that the bonds in question shall be certified by the state controller and that all bonds so certified shall be legal investments for all trust funds, and for the funds of all insurance companies, commercial and savings banks, trust companies, and for state school funds, and be placed on a par with bonds of municipalities, counties, and school districts, as to investment and security. Thus, in place of the unlimited authority of boards of directors, under the original Wright act, to issue irrigation district bonds with no report whatever as to feasibility, the state government has now provided that bonds of districts meeting the legal and financial requirements of a state commission, while not in any way endorsed by the state, shall be on a par for investment purposes with what are usually classed as standard securities.[1]

Changes in the bonding provision of the district law made in 1913 were important because, among other things, they marked a beginning in a larger measure of state supervision and radically changed the bond provisions.[2] By amending section 30 of the act of 1897 they provide that engineering estimates of the cost of new works shall be made by a competent irrigation engineer whose report must be submitted to the state engineer, the latter to report his conclusions within ninety days, particularly with reference to the water supply available and the feasibility of the proposed enterprise. This change was modeled after the Idaho law. While it does not give the state engineer veto power over a proposed bond issue, it requires his report thereon, and it is the presumption that no bond issue can be voted, or if voted, be sold, in the face of an unfavorable report from the state engineer. An amendment to section 31 makes the bonds payable from the 21st to the 40th years after issue, instead of from the 21st to the 30th years

[1]The irrigation district commission has already passed favorably on bond issues for South San Joaquin, Oakdale, Modesto, Turlock, Anderson-Cottonwood, and San Ysidro districts, and has made investigations, as provided in the act, in Imperial, Alpaugh, and Terra Bella districts. Since this was first printed the commission has passed favorably on bond issues for Imperial district.

[2]Statutes 1913, chapter 578. The legislature of 1913 also passed the following: Statutes 1913, chapter 96, p. 107, amending section 1 of chapter 522, Statutes 1907, relating to deposit of money belonging to any county or municipality in any bank in the state, by including irrigation district bonds among the bonds that may be lawfully given as security for such deposit; Statutes 1913, chapter 97, p. 101, amending section 676 of the Political Code to permit the proceeds from the sale of state school lands under certain conditions to be invested in irrigation district bonds; and Statutes 1913, chapter 98, p. 108, amending section 3, Statutes 1907, chapter 50, p. 67, to permit the state treasurer under certain conditions to accept irrigation district bonds as security for state funds.

previously provided. The same amendment changes the rate of interest on irrigation district bonds from 5 per cent to not to exceed 6 per cent, the rate to be determined by the directors. An amendment to section 62 removes the prohibition against the sale of bonds for less than par and permits them to be sold to the highest responsible bidder. A new section (32½) provides that bonds authorized before the above amendment and not sold may be sold for less than par if such sale is sanctioned at a special election by a two-thirds vote. Another new section (54½) provides that during the construction of works under the proceeds of a bond issue the secretary of the district must within a week after each regular board meeting send to the state engineer copies of all reports on works under way, together with a financial statement, and gives authority to the state engineer to examine the affairs of the district at any time and to call for special information and reports thereon.[1]

A bond amendment made in 1915[2] provides that in all cases subsequent to January 1, 1910, where directors have passed a resolution calling for a bond election and where four-fifths of the electors voting have favored such issue, and the directors have provided for it, all proceedings connected therewith and all bonds sold hitherto or later are valid.

ORGANIZATION.

The sections of the act of 1897 relating to organization were amended in 1909,[3] 1911,[4] 1913,[5] and 1915.[6] The most important of the amendments were made in 1911 and 1913. In 1911 holders of possessory rights under receipts or other evidence of the rights of entrymen or purchasers under any law of the United States or of California were

[1]The legislature of 1915 adopted a number of important amendments to the district act covering, among other things, matters pertaining to organization, co-operation with the federal government, and supervision by the state engineer. (Assembly Bill No. 1188.) Just before the end of the session a new section was added, in the interest of the proposed development in San Joaquin Valley, which would make a petition for the organization of a district sufficient if it should be signed by 60 per cent of the holders of title or evidence of title to the lands to be included, provided such 60 per cent should represent 25 per cent in value of such land. Opposition to this proposed new section and to at least one other feature, of relatively minor general importance, prevented the measure from receiving executive approval. The bill gave the state engineer veto power over the organization of new districts. Section 18 of the act of 1897 was amended to provide that water should be apportioned ratably only "as far as practicable," and the right of assigning the share due any taxpayer was taken away. Section 30 was amended to make more specific former provisions regarding the report of the state engineer on bond issues; also the petition necessary prior to calling of a bond election was eliminated and the number of votes necessary to carry a bond election was changed from a majority to two-thirds. Section 54½ was amended to provide more specifically than before for reports to the state engineer of progress on work being done with the proceeds of bond issues and a new section (54¾) made it the duty of the state engineer to give information to persons contemplating the formation of new districts and also to advise freely with the governing boards of organized districts. In all the bill amended seventeen sections of the act of 1897 and added four new sections.

[2]Statutes 1915, chapter 507.

[3]Statutes 1909, chapter 22, p. 12.

[4]Statutes 1911, chapter 317; Statutes 1911 (extra session), chapter 36, p. 139.

[5]Statutes 1913, chapter 578.

[6]Statutes 1915, chapter 696.

made eligible to sign a petition for the formation of an irrigation district. At the extra session of 1911 section 4 was amended to abolish all right of appeal from the finding of the board of supervisors as to the genuineness and sufficiency of a petition and notice for organization, except by the state itself. The principal change in organization procedure was made in 1913, sections 2 and 3 being amended to provide that copies of petitions to boards of supervisors for the formation of irrigation districts shall be filed in the office of the state engineer together with copies of resolutions of the supervisors relating thereto, and also to provide for a report by the state engineer as to "whether any condition or conditions exist that would justify him in reporting against the organization of the proposed district." The amendment gives the state engineer but thirty days in which to file his report, and it is to be noted that the report called for is merely a negative one. These provisions, like those having to do with the report by the state engineer on proposed bond issues, already cited, were patterned after the Idaho law. If the state engineer reports unfavorably as to the feasibility of a proposed district no further action can be taken by the supervisors unless they be requested in writing by three-fourths of the holders of title or evidence of title to grant the petition; except that in lieu of such request the supervisors may modify the plans in accordance with recommendations by the state engineer. The act providing this supervision by the state engineer also amended section 61 to provide that before the collection of any assessment in any district the directors may incur indebtedness up to $2,000.00 for districts containing 4,000 acres or under, or in the case of districts exceeding 4,000 acres, to one-half as many dollars as there are acres in the district, up to $50,000.00, warrants bearing 7 per cent per annum (changed by Statutes 1915, chapter 696, to not to exceed 7 per cent) to be issued in payment of such indebtedness. A further addition to this section in 1911 specified that demand warrants presented when no funds were available should bear interest at the rate of 5 per cent; also that whenever money was available for payment of all outstanding demand warrants or whenever the directors ordered that all warrants presented for payment prior to a certain date be paid and money was available therefor, interest thereon should cease with the first date of publication of notice of these facts. By statute of 1915[1] the 5 per cent rate of interest on demand warrants after presentation for payment was changed to a rate to be determined by the board of directors, but not exceeding 7 per cent. The amendment affecting organization made in 1915 among other things specifies that lands covered in an organization petition need not consist of contiguous parcels and that in certain cases the "actual" owners of property shall be considered the owners for all of the purposes of the act,

[1]Statutes 1915, chapter 696.

that owners of undivided interests may sign for such interests and that each owner shall be considered as one assessment payer, and that guardians, executors, administrators, or other persons holding property in a trust capacity may sign any petition provided for in the act when authorized to do so. Section 72 is amended to provide that in confirmation proceedings all findings of fact or conclusions of boards of directors or of boards of supervisors shall be conclusive unless contested within six months after such findings or conclusions are made.

ELECTIONS.

A number of changes have been made in the procedure covering elections in irrigation districts. In 1909[1] two sections were amended in matters of detail. In 1915[2] an addition was made to section 19 providing that if an election for officers is not held as provided by law a special election shall be called on petition of 10 per cent of the electors residing within the district. This amendment was made to meet a situation in one of the old districts organized in San Bernardino County. Up to 1915 section 5, relating to election of the first board of directors, provided that if requested in the organization petition to do so, boards of supervisors might provide for three instead of five directors, to be elected by divisions or at large, as specified in the petition. Section 28 formerly permitted boards of directors, on petition of a majority of the holders of title or evidence of title of a district, to change the number of directors to three or five, to be elected by divisions or at large as petitioned. By amendment in 1915[3] such action is made mandatory on petition rather than permissive, but it is provided that if elected at large the directors shall nevertheless be elected to represent separate divisions, of which they shall be residents. It is to be noted that section 26, which has not been changed, specifies that a director shall be a resident and freeholder of the irrigation district but not necessarily of the division for which elected. It is also to be noted that in practice, directors of all present California irrigation districts are residents of their respective divisions.

Two innovations, so far as concerns irrigation districts, that may be classed with sections dealing with elections were adopted by the California legislature in 1909 and 1911 (extra session)—nomination by petition, and the recall. Prior to 1909 the law made no provisions for nominations, but specified in section 22 that the provisions of the general election laws should not apply to irrigation district elections. Sections 22*a* and 22*b* were added in 1909,[4] specifying that ballots be

[1]Statutes 1909, chapter 692.
[2]Statutes 1915, chapter 677.
[3]Statutes 1915, chapter 696.
[4]Statutes 1909, chapter 692.

provided with the names of candidates and that nominations can be made by petition of ten or more electors. At the extra session of 1911[1] section 28½ was added providing for the recall of any elective officer at any time. Under this amendment a number of recall elections have been held in Modesto and Turlock districts, and one has been held in Oakdale district, but only in two instances has such an election been successful.

EXCLUSION OF LANDS.

By an amendment to section 78 of the act of 1897 adopted in 1905[2] a former provision that no lands within city or town limits and no lands subdivided therefor should be excluded from irrigation districts was eliminated. A further amendment to the same section in 1913[3] provided that lands irrigated by underground pumped waters and benefited by subirrigation from district irrigation or drainage works can not claim exclusion, but that they shall be assessable only for interest and principal of bonds if thus irrigated at the time of organization and still exclusively so irrigated each year. This amendment was passed to meet a situation in South San Joaquin district where the court of appeals had held that a certain landowner having a pumping plant was entitled to have his land excluded[4] A third, relatively unimportant, amendment to the same section was adopted in 1915.[5]

INCLUSION OF LANDS.

The provisions of the act of 1897 relating to inclusion of lands received their first amendment in 1915.[6] A series of provisos was added to section 90 permitting adjacent public land to be included without a petition and specifying that where the inclusion of land would injure land already in a district by the impairment of its water right or by increasing the expense of water, a priority of water right for the lands already in or additional annual payments or other just consideration from the lands to be included may be prescribed as conditions to inclusion. Section 91 was amended to require petitioners for inclusion to furnish an undertaking conditional on the failure of the inclusion elections.

SALARY OF DIRECTORS.

The act of 1897 allowed directors three dollars per day for time employed in district business. An amendment in 1909[7] substituted four dollars per day and an allowance of ten cents per mile traveled

[1]Statutes 1911 (extra session), chapter 34, p. 135.
[2]Statutes 1905, chapter XXXIII, p. 27.
[3]Statutes 1913, chapter 367, p. 781.
[4]*Harelson* vs. *South San Joaquin Irrigation District et al.*, 128 Pac. 1010.
[5]Statutes 1915, chapter 506.
[6]Statutes 1915, chapter 696.
[7]Statutes 1909, chapter 692.

from the residences of the directors to the office of the board. A further amendment in 1915[1] adds a proviso that in irrigation districts containing 500,000 acres or more, directors shall, in lieu of a per diem allowance, each receive $150.00 per month. This amendment was added at the instance of Imperial district which at present is the only one to which it can refer.

LEASE OF PROPERTY.

A statute passed in 1901[2] added section 15½ to the act of 1897, providing that boards of directors may lease the canal system of a district. This amendment was made at the instance of those seeking to take over the canal of the old Central irrigation district in Sacramento Valley. This section was amended in 1911[3] to extend the authority for lease of a system to any part thereof.

DISSOLUTION.

The original Wright act provided no means for the dissolution of irrigation districts and when an effort was made to dissolve Selma district shortly after its formation, the superior court of Fresno County held that it had no jurisdiction because of the lack in the Wright act. This decision was affirmed by the supreme court in May, 1893, which held that the general power of the courts to decree a dissolution of irrigation districts was no greater than in the case of municipal corporations proper, which the courts had no power to dissolve for failure to accomplish the purpose of their organization.[4] A supplemental act covering disorganization was passed in 1893 and amended in 1897, but was not incorporated in the general act of 1897, although probably not repealed by it. The matter was, however, covered by a supplementary act in 1903,[5] and this act was amended in 1909,[6] 1911,[7] 1913,[8] and 1915.[9] An amendment to the main irrigation district act of 1897, which adds section 47½, makes a further slight change. Under the act as amended dissolution of a district may be proposed by a majority of the real property owners representing a majority in value thereof. The petition of these owners must set forth all indebtedness of the district other than that barred by law prior to filing, the estimated cost of the dissolution, all assets of the district, and the proposed proposition for settlement, if assented to by the creditors of the district, or if a provision is made for the payment of creditors not assenting. The

[1]Statutes 1915, chapter 696.
[2]Statutes 1901, chapter CCLXIX, p. 815.
[3]Statutes 1911, chapter 317.
[4]*People* vs. *Selma Irrigation District*, 98 Cal. 206.
[5]Statutes 1903, chapter V, p. 3.
[6]Statutes 1909, chapter 91, p. 139.
[7]Statutes 1911 (extra session), chapter 26, p. 118.
[8]Statutes 1913, chapter 39, p. 39.
[9]Statutes 1915, chapter 525.

question of dissolution is then referred to an election which requires a two-thirds affirmative vote to carry, after which it is in the hands of the court. Section 7 of the act provides that a corporation may be organized to acquire the assets and operate the irrigation system of a district proposing to dissolve. Under this act at least fifteen of the old Wright districts have been dissolved.

ASSESSMENTS.

An act of 1909[1] permits boards of directors of irrigation districts to provide for the payment of assessments in two installments instead of one. It is specified in this act that assessments levied under section 34 of the act of 1897, providing for completion of works, shall not be affected. Otherwise, upon petition of a majority of the assessment payers in a district the board of directors may provide that assessments be paid in two installments instead of one. By another act,[2] section 35 of the act of 1897, relating to the duties of the assessor, is amended to provide that improvements on any lands or town lots within an irrigation district shall be exempt from taxation for any of the purposes mentioned in the irrigation district act and the word "improvements" is defined to include trees, vines, alfalfa, all growing crops, and all buildings or structures, with the proviso that the exemption of improvements for taxation shall not apply in districts organized at the time of this amendment without the approval by a majority vote of the resident holders of title to lands within the district subject to taxation therein. Another statute of 1909[3] provides that in the annual levying of assessments sufficient shall be included to pay in full the amount of any contract or obligation of a district which shall have been reduced to judgment. A statute of 1911[4] amends section 39 of the act of 1897 by requiring that in the annual levying of assessments the boards of directors shall add sufficient to pay in full all sums due or that shall become due from the district before the time for levying the next annual assessment on account of rentals or charges for lands, water, or water rights acquired under lease or contract. Another statute in 1911[5] amends section 59 of the act of 1897, which relates to special assessments, by adding three provisos at the end thereof: (1) that four-fifths of the board of directors of a district may by resolution levy in any one year an assessment up to two per cent of the assessed valuation within the district, but not exceeding $75,000.00 without a special election; (2) that a vote must, however, be taken on such assessment on petition of 15 per cent of the qualified voters in the

[1]Statutes 1909, chapter 274, p. 415.
[2]Statutes 1909, chapter 303, p. 461.
[3]Statutes 1909, chapter 55, p. 46.
[4]Statutes 1911, chapter 317.
[5]Statutes 1911, chapter 588, p. 1111.

district voting at the last preceding general election in the district; and (3) that in case of an unexpected emergency by which the flow of water in the district canal is interrupted, an indebtedness may by a four-fifths vote of the board be incurred not exceeding $40,000.00 in any one year. A statute in 1913[1] further amends section 39, relating to the levying and collection of assessments, by providing among other things, that it shall be the duty of the district attorney of each county in which the office of any irrigation district is located, to ascertain each year whether the duties relating to the levying and collection of assessments have been performed and on showing of neglect to so notify the board of supervisors or other officials required to perform such duties, and that on failure of the supervisors or other officials to perform the neglected duties the district attorney shall take such action in court as may be necessary to compel performance, provided that for the enforcement of the levying and collection of any assessment "hereafter required to be levied and collected" for the payment of any debt "hereafter incurred," the attorney general of the state shall take appropriate action on failure of the district attorney to do so. A further act in 1913[2] amends sections 41 and 43 by providing that the penalty on delinquent assessments shall be 10 per cent instead of 5 per cent of the amount thereof. A statute passed in 1909[3] amended section 47 by providing that redemptions of property sold for district taxes could be made within five years from the date of sale or at any time thereafter before a deed had been made and delivered, in place of the two-year period previously allowed; also that where property had been sold to the district it might be redeemed at any time before the district had disposed of it. A further amendment in 1915[4] provides that directors may direct the district collector not to sell property on a delinquent list, but in lieu thereof to sue the owners in the districts named for collection. A supplementary statute passed in 1913[5] amends section 3653 of the Political Code by providing that on request county assessors must furnish to irrigation districts copies of assessment rolls covering lands therein.

POWERS OF DIRECTORS.

Changes relating to powers of directors of irrigation districts have been made in 1911, 1913, and 1915. The amendment in 1911[6] permits districts to acquire and hold the stock of other corporations owning waters, canals, waterworks, franchises, concessions, or rights. The

[1]Statutes 1913, chapter 60, p. 59.
[2]Statutes 1913, chapter 578.
[3]Statutes 1909, chapter 284, p. 429.
[4]Statutes 1915, chapter 696.
[5]Statutes 1913, chapter 386, p. 814.
[6]Statutes 1911, chapter 317.

change made in 1913 was in the form of a constitutional amendment which was adopted by the people in November, 1914. It authorizes irrigation districts, "for the purpose of acquiring the control of any entire international water system necessary for its use and purposes, a part of which is situated in the United States, and a part thereof in a foreign country," to acquire the stock of any foreign corporation "which is the owner of, or which holds the title to the part of such system situated in a foreign country."[1] This amendment was adopted to enable Imperial irrigation district to acquire that portion of the irrigation system of the California Development Company that is situated in Mexico. The same purpose actuated two amendments to the district law adopted in 1915[2] adding section 61*b* and section 61*c*. The former permits directors of irrigation districts of over 500,000 acres to acquire by purchase or condemnation an irrigation system supplying lands therein and where a part of such system lies outside of the state, to exchange district bonds for all or a portion of the system or for interest in or stock of a corporation owning such system; the latter provides that where directors have exchanged or agreed to exchange district bonds for property rights as authorized in the previous section the court shall in any proceeding under its provisions determine the validity of all bonds issued or to be issued under contracts for such exchange.

MISCELLANEOUS SPECIAL AND SUPPLEMENTARY ACTS.

In addition to amendments to the act of 1897 a number of special and supplementary acts have been passed affecting the irrigation district law of the state.

Drainage.—A statute of 1907[3] provides that irrigation districts may provide for drainage under the same laws that permit them to finance and construct irrigation works. Under this act drainage works have been built by Modesto and Turlock districts and a beginning has been made in South San Joaquin district.

Power.—A statute of 1911[4] amended section 1410 of the Civil Code of California relating to rights to water which may be acquired by appropriation by providing that no water for power may be appropriated for more than twenty-five years except by a municipal corporation other than an irrigation or lighting district, or by an irrigation district when for subsidiary use within its own limits, etc. This act has, however, been superseded by the water commission act of 1913.[5]

[1] Session Laws 1913, constitutional amendments and concurrent and joint resolutions, chapter 95.
[2] Statutes 1915, chapter 655.
[3] Statutes 1907, chapter 298, p. 569.
[4] Statutes 1911, chapter 407, p. 821.
[5] Statutes 1913, chapter 586.

Agricultural Expert.—A statute of 1913[1] authorizes boards of directors of irrigation districts to employ agricultural experts and assistants to supervise the construction of works, advise with farmers, and conduct experiments.

Water Districts.—An act known as the "California Irrigation Act,"[2] which seeks to provide a policy relating to storage, diversion, and use of water, in cooperation between the state and the United States or otherwise, authorizes irrigation districts to reorganize under such act. This legislation was passed primarily in the interests of what is known as the "Iron Canyon Project" in upper Sacramento Valley and was amended to permit irrigation districts to reorganize under it at the instance of some of those seeking to consolidate into a number of cooperating irrigation districts all of the irrigation systems taking water from Kings River.

Legislative Validation of Irrigation Districts.—Beginning in 1911 irrigation districts in California have adopted the practice of obtaining special legislative acts of validation. Such acts were passed affecting Turlock district,[3] Oakdale district,[4] Modesto district,[5] South San Joaquin district,[6] and Imperial district[7] in 1911; San Ysidro district in 1913[8]; and Anderson-Cottonwood district,[9] Oakdale district,[10] La Mesa, Lemon Grove, and Spring Valley district,[11] and Waterford district,[12] in 1915.

Flood Protection.—An emergency act passed in 1915[13] in the interest of Imperial district provided that districts having an area of more than 500,000 acres shall have authority to construct levees and protect the lands within such districts from damage resulting from floods. For that purpose directors of such districts are given authority to spend money jointly with other agencies or alone, and it is provided that when bonds for flood protection have been authorized but not sold, directors may borrow the amount of such bonds and repay the loan out of bond sales, and in addition may borrow in any one year up to $200,000.00 at interest not exceeding 7 per cent. Under this act Imperial district borrowed $200,000.00 in the spring of 1915 for cooperation with the federal government and for independent action in flood control.

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[1]Statutes 1913, chapter 72, p. 75.
[2]Statutes 1915, chapter 621.
[3]Statutes 1911, chapter 95, p. 261.
[4]Statutes 1911, chapter 96, p. 262.
[5]Statutes 1911, chapter 97, p. 262.
[6]Statutes 1911, chapter 98, p. 262.
[7]Statutes 1911 (extra session), chapter 27, p. 119.
[8]Statutes 1913, chapter 21, p. 25.
[9]Statutes 1915, chapter 68.
[10]Statutes 1915, chapter 50.
[11]Statutes 1915, chapter 156.
[12]Statutes 1915, chapter 632.
[13]Statutes 1915, chapter 1.

Imperial District Bonds.—A special act of 1915[1] validated an Imperial district bond issue of $3,500,000.00, dated January 1, 1915. This act was intended to assist Imperial district in its negotiations for the purchase of the property of the California Development Company.

Purchase of System by Imperial Irrigation District.—A special act of 1915[2] authorized Imperial irrigation district to condemn or purchase the system of the California Development Company in California and the stock of the Mexican corporation owning the portion of the system that lies in Mexico, and in this connection to exchange district bonds not exceeding in amount $3,000,000.00.

Constitutional Amendments.—The constitution of California has been amended six times since 1902 in the interest of irrigation districts, or in such manner as to affect irrigation districts, or a single district. Section 1¾ of Article XIII, as approved November 4, 1902, exempts irrigation district bonds from taxation within California. Section 13½ of Article XI, as approved November 6, 1906, permitted irrigation districts to make their bonds payable at any place within the United States designated in said bonds. This section was further amended November 3, 1914, to permit irrigation districts to make their bonds and the interest thereon payable "at any place or places within or outside of the United States, and in any money, domestic or foreign, designated in said bonds." Section 16½ of Article XI, as approved November 5, 1912, permits California irrigation district bonds to be deposited as security for state, county, or municipal funds.

Section 13 of Article XI, as approved November 3, 1914, permits the legislature to provide "for the supervision, regulation and conduct, in such manner as it may determine, of the affairs of irrigation districts * * *." Finally, section 31 of Article IV, as approved November 3, 1914, provides "that irrigation districts for the purpose of acquiring the control of any entire international water system necessary for its use and purposes, a part of which is situated in the United States and a part thereof in a foreign country, may, in the manner authorized by law, acquire the stock of any foreign corporation, which is the owner of, or which holds the title to, the part of such system situated in a foreign country,"—an amendment purely in the interest of Imperial irrigation district, and designed to permit it to acquire full control of the works of the California Development Company lying in Mexico.

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[1]Statutes 1915, chapter 17.
[2]Statutes 1915, chapter 172.

STATUS OF CALIFORNIA DISTRICTS JULY 1, 1915.[1]

Altogether fifty-seven irrigation districts have been organized in California since the passage of the Wright act in 1887, of which nine have been formed since the passage of the act of 1897. Counting eight of the old districts—Browns Valley, Modesto, Turlock, Alta, Tulare, Little Rock Creek, Big Rock Creek, and Walnut—seventeen out of the fifty-seven are in existence and twelve are operating. Of the remaining five, Big Rock Creek district has just been revived, Anderson-Cottonwood, La Mesa, Lemon Grove and Spring Valley, and Imperial, although fully organized and although they have all voted bonds, have not yet become operating districts, and Waterford and Alpaugh have not yet adopted plans or voted bonds.

In the following pages a somewhat detailed account is given of the status of the sixteen present active[2] districts, with emphasis laid rather on management than on works. That the people of the best California irrigation districts are developing a reasonable efficiency in handling their district business problems there can be no question; yet it is by no means certain that a higher efficiency would not result from a larger centralization of administrative authority. Only in the case of Imperial district has a high salaried general manager been employed, and even in that instance business questions seem largely to be retained within the jurisdiction of the directors. Further, this district is not yet fully operating. That it is proposed in Imperial district to have the directors retain a considerable administrative jurisdiction is evidenced by the passage in 1915, at the instance of Imperial district, of an amendment to the irrigation district law[3] by which directors in districts containing over 500,000 acres shall receive salaries of $150.00 per month in lieu of $4.00 per day received previously. In Modesto, Turlock, Oakdale, and South San Joaquin districts, as will be seen, the directors have been accustomed to devote much more time to district business than

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[1]Since this was written West Side, Terra Bella, Lindsay-Strathmore, Carmichael, and Southern Lassen irrigation districts have been formed, the latter without investigation and report by the State Engineer. The locations and areas of these four districts are as follows, according to records filed with the State Department of Engineering: West Side, near Tracy, area 11,700 acres; Terra Bella, surrounding Terra Bella, area 12,500 acres; Lindsay-Strathmore, east of Lindsay and Strathmore, area 15,775 acres; Carmichael, near Fair Oaks, area 3,113 acres; Southern Lassen, near Doyle, area approximately 30,000 acres. The formation of additional districts is, or recently has been, under consideration at Paradise, Thermalito, Oroville, Willows, Princeton, Ione, Morgan Hill, Merced, Madera, Stratton, and Cardiff, San Diego County. Since this was first printed the following additional districts have been formed: Cardiff, near San Diego, area about 700 acres; Honey Lake, near Amadee, area approximately 31,000 acres; Paradise, area 11,250 acres; Stratford, near Lemoore, area 9,200 acres; Webster, near Madera, 15,000 acres.

[2]The term "active" is used here to designate districts that are actually active in construction or operation; or that have been only recently organized and are now in the preliminary stages looking to real activity.

[3]Statutes 1915, chapter 696.

PLATE III.

CALIFORNIA IRRIGATION DISTRICTS, FEBRUARY 1, 1916.

1. Anderson-Cottonwood
2. Browns Valley
3. Oakdale
4. South San Joaquin
5. Waterford
6. Modesto
7. Turlock
8. Alta
9. Tulare
10. Alpaugh
11. Little Rock Creek
12. Big Rock Creek
13. Black Rock
14. Walnut
15. Mesa, Lemon Grove and Spring Valley
16. San Ysidro
17. Imperial
18. South Lassen
19. Carmichael
20. Westside
21. Lindsay-Strathmore
22. Terra Bella

IRRIGATION DISTRICTS ORGANIZED IN 1916.

23. Honey Lake
24. Long Valley Creek
25. Baxter Creek
26. Paradise
27. Princeton-Cordova-Glenn
28. Webster
29. Stratford
30. Cardiff

Sketch map of California, showing location of active or recently organized California irrigation districts, February 1, 1916.

boards of directors of most commercial and industrial enterprises devote to those enterprises. It would seem, however, that even in these districts sentiment will gradually crystallize in favor of giving more and more administrative authority to the principal operating officer, whether that officer be styled a general manager or an engineer and superintendent. The logical ultimate development would seem to be to an able and well-paid manager to whom all employees, from attorney to ditchtenders, shall report, and with whom the directors shall advise and to whom they shall look for that efficient business administration which most irrigation districts have in the past lacked.

California irrigation districts have not wanted for their full share of internal friction, yet the history of such districts as Modesto and Turlock shows that this is decreasing as the people become more accustomed to irrigation farming and more experienced in cooperation and local self-government. A fundamental of good irrigation district government is a consciousness on the part of the people of the district of a community interest and of individual community responsibility. In the more important of the successful California irrigation districts such consciousness has been quite well developed, but the efforts it has stimulated have not always been constructive. One of the problems of irrigation districts, therefore, is to stimulate a constructive rather than a merely scolding interest on the part of the irrigators.

The financial management of California irrigation districts has not been free from difficulties and under the earlier law, as has been shown, those difficulties were not always met squarely. From the refunding act of 1897 down to the amendments of 1915, however, California irrigation districts and those interested in them have been endeavoring, usually with sincerity, to simplify and make more businesslike irrigation district financial operations. The development of the changes in the financial provisions of the district law is shown under a former heading (p. 48), but in reading of the present status of the districts now active some attention to financial affairs, especially the levying and collection of district taxes, is believed to be worth while. No mention is made of the extent of delinquencies in the payment of district taxes, although that matter was inquired into. In the well established districts delinquencies are negligible and are much more than cared for by the extra levy permitted by the district law. In one or two of the newer districts and in the old districts recently reorganized delinquencies have been large enough to constitute a distinct annoyance if not a problem; yet there is no evidence that if a problem is involved, it will not be worked out satisfactorily, or even that it is of sufficient importance to jeopardize the success of the enterprise affected. In no case has one of the fully reorganized districts or one of the new and

already established districts failed in meeting bond interest, or bond principal when due.

The law requires that property shall be assessed for district purposes at its full cash value. It is realized that assessments for both special and general taxes levied by counties and municipalities are bound to vary, no matter for what purpose they are levied. Therefore, it is not unexpected or surprising to find similar differences in the valuations placed on land of the same general character in irrigation districts. In irrigation districts, however, quite different methods in reaching valuations are followed, and it is to these methods that it has been deemed worth while to call attention in discussing conditions in the various districts now active.

Whenever the necessary data could be readily obtained operating expenses have been given and water delivery methods described quite fully. These are matters of every-day, practical interest to operating officials, which is the justification for including them.

ANDERSON-COTTONWOOD.

The historical data covering early operations under the Wright act already given disclosed the fact that of seven districts formed under that act in Sacramento Valley from 1887 to 1891, only Browns Valley district is now active, and with even that district only partially operating under the district law. It is, therefore, especially interesting that an important section of Sacramento Valley should now have turned to the district form of organization as a means of furnishing much needed irrigation water.

Anderson-Cottonwood irrigation district, extending along Sacramento River from Redding to below Cottonwood Creek, was organized July 14, 1914, by a vote of 512 to 17. While mostly lying west of the Sacramento, a narrow strip of land across the Sacramento connects the main portion of the district with about 3,800 acres east of the Sacramento on Churn Creek bottoms and Stillwater plains. The total area in the district, as voted, was approximately 32,500 acres, but several holdings have since been excluded and the exclusion of several others has been asked for and was under consideration by the directors in July, 1915. Generally speaking, the land embraced consists of first and second bottom river lands, first bench, and rolling plains. More technically, the lower lands are mostly classified by the bureau of soils[1] as Sacramento silt loam, Sacramento fine sandy loam, Anderson fine sandy loam, and Sacramento loam; the next higher mostly as Anderson gravelly loam; and the higher or plains areas chiefly as Redding loam and Redding gravelly loam. Although some of the plains land has been

[1]United States Department of Agriculture, Bureau of Soils. Soil Survey of the Redding Area, California.

dry-farmed to grain and a little is still so farmed under summer-fallowing, agricultural production has mainly been confined to the two lower soils and to the largest extent to the bottoms. On the latter a considerable development in alfalfa and in deciduous fruits has occurred, with very little land irrigated. With water supplied as now proposed by the new district, and carefully used so as to avoid overwetting of the lower areas, production should be very appreciably increased on the fruit, alfalfa, and grain lands now under crop, and some of the higher lands now chiefly of value only for grazing should be given a substantial value for irrigation farming. The depth and composition of the higher lands both vary, and some of these lands are not likely to be very productive, although some seem well suited to certain types of orchard culture which an irrigation supply will make possible.

The irrigation system planned by Anderson-Cottonwood district, and on the basis of which bonds to the amount of $480,000.00[1] were carried June 18, 1915, by a vote of 503 to 94, calls for a main canal from Redding to the south side of Cottonwood Creek in northern Tehama County, a total distance approximating 30 miles. Water is to be diverted, during low water stages, by a concrete flash-board dam 500 feet long at the head of the old "Wheel" ditch shortly above Redding. From that point the main part of the system is to consist, in the order given, of a concrete-lined tunnel 2,480 feet long and 10 feet in diameter under a part of the town of Redding; an open channel 4,000 feet long to a weir near Sacramento River to be so constructed as to provide for winter drainage and the flushing of the canal above; a branch leading across the Sacramento, called "Churn Creek main," and involving a concrete and cast-iron siphon under the Sacramento; a main open canal from the above-mentioned weir to the crossing of Cottonwood Creek; a concrete siphon under Cottonwood Creek; and an open canal from there to the end. The Churn Creek main, according to the plans, is to have four principal laterals, and the main canal on the west side a total of twenty. A pumping plant to cost with laterals $46,290.00 is planned for lifting water from the Churn Creek branch 38 feet to the small area on Stillwater plains that lies in the district. Three other pumping plants, estimated to cost a total of $8,520.00, will be necessary to raise water not exceeding 20 feet to small areas in the district lying above the west side main. The duty of water figured by the engineer of the district is one cubic foot per second for each 100 acres irrigated and the main canal is designed to carry at its head at least 365 cubic feet per second. Pumping plants are designed to deliver three acre-feet per acre per season over the areas served by them and all laterals, except two to carry

[1]The estimates of the engineers employed by the district called for an expenditure of $359,950, but the amount necessary was raised by the State Engineer to the amount voted.

50 cubic feet per second each, are designed for 32 cubic feet per second. The acre-cost of pumping has been estimated to be not to exceed $2.70 in the case of the plant on Churn Creek bottoms and not to exceed $2.05 in the case of the others. The estimated acre-cost for operation, including maintenance, interest, replacement, and distribution, is $1.20, counting on the full area of 32,500 acres within original boundaries.

It is, of course, not possible to forecast the success of Anderson-Cottonwood irrigation district any more than of any other undertaking of similar character. That the enterprise is justified there can, however, be no question. The engineering problems involved are admittedly not serious and the engineering plans adopted have, with some modification as to costs, been approved by the State Department of Engineering. Assuming that the slight opposition that has been voiced will not develop into obstruction, that the federal government will interpose no objection to the proposed diversion from Sacramento River, and that the bonds that have been voted can be economically disposed of and the proposed works completed, the enterprise will still have before it the problems always attending the changing of the agriculture of a community from a dry to an irrigation basis. Most of the land holdings are now too large to be farmed economically under irrigation, so that as a rule they must be cut up as soon as water is available and annual water charges levied. With few exceptions the present landowners are untrained either in irrigation practice or in irrigation farming, and their first task will be to learn to irrigate and to grow and dispose of the crops that are best adapted to the soils and the situations of the district, and that will be profitable. Some difficulties will be encountered in distributing irrigation water over uneven surfaces and restraint will be needed to prevent washing of the steeper lands and overwetting of the bottoms, especially where there are depressions. The large flow of Sacramento River at the proposed point of diversion will insure an ample water supply and this will so tend to encourage overuse that a strict system of measuring water to irrigators and of at least partially basing the annual water charge on the quantity used seems essential. At this writing a difficult administrative problem before the district is that of levying district assessments. The nonproductivity of the plains lands without irrigation and the local belief that these lands will undergo a greater relative increase in value under irrigation than the already productive bottoms has convinced the owners of the bottoms that they should not be taxed a greater amount for construction expenses than the owners of the plains lands. The 1914 county assessment of the plains lands was generally about $7.00 per acre, while that of the bottoms reached as high as $40.00. Under these conditions the important practical question before the assessor became: Is it possible, under the provision of the law requiring all lands to be assessed at their full cash

value, to assess the plains and bottoms at the same figure? An equal assessment seems to have been agreed on by the landowners as being desirable, but a feasible adjustment of the matter had not yet been worked out when the district was visited in July, 1915.

BROWNS VALLEY.

The present status of this district is partially given in connection with its history. Browns Valley is not a "valley," strictly speaking, but rather a series of low rolling hills and valleys. The hills are higher and the valley depressions consequently more pronounced as the Sierra are approached on the east, while on the west the lands grade off to lower rolling plains. It is this unevenness in topography that limits the area in the district susceptible of gravity irrigation from the system. Except on the west, which is barren, the hills are covered with scrub oak and pine, with in some places a rather dense undergrowth of brush. The crops grown include a limited amount of alfalfa, small fruits, some deciduous and citrus fruits, and olives, and there is a considerable acreage of wild meadows, which, with the alfalfa, make dairying rather prominent. The original crib dam at the head of the canal has been replaced by a concrete structure and from there to the power house at Colgate the canal capacity has been increased, for power purposes, to about 700 cubic feet per second, the cost of this having been met by the power company with which the district has an agreement. From Colgate to the lower power house along Dry Creek the capacity is said to be about 50 to 70 cubic feet per second. In July, 1915, the power company reported to the district the carrying of 1,600 inches, or 40 cubic feet per second, about 40 miles above. The district has in all about 100 miles of main canals and laterals.

Having, under its agreement with the Pacific Gas and Electric Company, only to care for water delivery and maintenance of the laterals, the operating expenses of the district are not high. The amount due to the district under its contract with the Pacific Gas and Electric Company is uncertain, but is believed by some of the officers of the district not to exceed 1,800 or 2,000 inches. In 1915 about 1,200 inches is being received, all of which is used. Water is sold to the irrigators at the rate of $3.00 per miner's inch per season, measured under a 6-inch pressure at each point of delivery, 75 inches being about a maximum "head," and each irrigator running water continuously during the irrigation season, which in dry years may extend from March to November. During the winter season stock water is kept in the ditches. No record is kept of the amount of land irrigated, nor is the exact duty of water under the system known. From such general observations as were made it was concluded that the area receiving water in 1915 does not exceed 2,500 acres. A feeling is growing in the district that a more careful

use of water and a rotation system of delivery must be put into effect in order to care for the increasing demand for water. About one-half of the land in the district is estimated by the president of the district to be held by owners who are now using no water; and even the owners who are irrigating are applying water to only about one-tenth of their holdings. As under the district law all have equal rights to the water controlled by the district, an additional supply must be obtained as more desire to irrigate, or the district must attempt the impossible task of making under 2,000 inches of water meet the needs of the irrigable portions of nearly 45,000 acres of land. At present there are 104 irrigators, of which five or six use as little water as one miner's inch.

The organization of Browns Valley district consists of a board of three directors elected at large, an assessor-collector, and two ditchtenders, one of the directors also acting as secretary, but receiving no compensation other than the $4.00 per diem allowed directors for each meeting of the board. The salary of the assessor-collector is $30.00 per annum. One of the ditchtenders acts as superintendent and receives $90.00 per month, with a reduced rate during the winter; the other ditchtender receiving $75.00 per month during the running of water. Neither ditchtender is furnished transportation by the district. The plan of not levying any assessments is still followed, all expenses being met by the water tolls. The directors of Browns Valley district, as in most other cases, are not entirely free from local troubles in the management of the district's business and the distribution of its water supply. There have recently been two small cases of litigation, one seeking to enjoin a water user from taking water without permission, and the other involving damages alleged to have been suffered to crops through failure by the district to deliver water. Both suits were decided wholly in favor of the district. A few have failed to pay water tolls and suits to collect are contemplated. On the whole, however, the affairs of the district run smoothly and an agriculture more satisfactory than that of earlier years, with its foundation in dairying and stock raising, is gradually developing.

SOUTH SAN JOAQUIN.

Thirty years ago agricultural conditions had reached that stage in certain portions of the northern part of San Joaquin Valley that further substantial progress was impossible without irrigation, even if there should not be a backward movement if nothing were done to change matters. The critical stage had been reached in the balance between profits from farming with water and without it. In the areas centering around Modesto there was no doubt that farms must either grow larger and be more extensively worked, or grow smaller and be farmed under the intensive culture water would make possible. It was out of these

PLATE IV.

Fig. 1.—Irrigated Rolling Meadow in Browns Valley Irrigation District.

Fig. 2.—Main Supply Ditch of Browns Valley Irrigation District.

conditions, as has previously been stated, that the Wright act of 1887 grew, and that this act was suited to these conditions, even if the act itself was incomplete, has been proven by the success of the two large districts formed at Modesto and Turlock. It was therefore not unnatural that the neighboring communities about Oakdale, Ripon, Manteca and Escalon should also eventually come to the district form of organization for irrigation development.

South San Joaquin irrigation district, lying wholly in San Joaquin County, was organized May 11, 1909, by a vote of 376 to 87. Previous efforts to obtain water date back to about 1889, when the San Joaquin Land and Water Company was formed to divert water from Stanislaus River.[1] After passing through many difficulties and later reorganization into the Stanislaus and San Joaquin Water Company, and again after passing into the hands of the South San Joaquin Canal and Irrigation Company and the Consolidated Stanislaus Water and Power Company, this enterprise that had been started in 1889 passed into the hands of a receiver and was sold at auction for a small fraction of the amount of money that had been invested in it, and by 1908 it was delivering water to several thousand acres. At that time, however, it was apparent that the old system must be enlarged and reconstructed and its owners, known as the Tulloch interests, began a canvass for the sale of additional water rights at $20.00 per acre. Like many water-right contracts, the contract offered to the farmers by the Tulloch system was not looked upon favorably, and the feeling gradually developed that if the farmers were to pay for building a new system they should own that system themselves. Meetings to discuss the situation were held at Manteca, Ripon, and elsewhere, and out of these meetings an irrigation bureau was formed by representative landowners in southern San Joaquin County for the avowed purpose of promoting the formation of an irrigation district. This irrigation bureau went about its work very effectively. Several hundred dollars was subscribed by the members and a newspaper, known as the "Irrigation Bulletin," was started to further the campaign. For about a year this publication, largely supported by its advertising pages, kept the matter of the proposed irrigation district constantly before the landowners in the area affected and the commercial and financial interests of the city of Stockton, and it was under the direction of the irrigation bureau that the lines of South San Joaquin irrigation district were laid out and organization of the district finally consummated.

From the beginning South San Joaquin irrigation district seems to have been fortunate in the selection of its officers, for, in spite of some

[1]Previous to this, however, and as early as about 1864, the property taken over by the San Joaquin Land and Water Company, or a portion of it, was owned by the San Joaquin County Water Company, but divested of title by foreclosure, after which the property came into the hands of one Abraham Schell.

mistakes that are acknowledged, it is doubtful if more efficiency and force have been put into the organization of any other irrigation district in the state, nor has any district been more loyally supported by the landowners. As soon as the district was organized an experienced and competent engineer was employed to lay out the proposed system, and on May 12, 1910, after a very thorough engineering study, an assessment of $35,000.00 was levied by a vote of 292 to 70, to pay for engineering expenses. The first bond issue, amounting to $1,875,000.00, and dated July 1, 1910, was authorized by a vote of 329 to 67. Of this issue $325,000.00 in bonds was used for the purchase of one-half interest in the old Tulloch system, and contracts were let jointly with Oakdale irrigation district for the construction of a diverting dam in Stanislaus River, and also, independently, for the construction of the canal system to the district. Through inability of the district to dispose of its bonds in the open market and the consequent necessity for letting its contracts only to those who would agree to buy sufficient of the bonds to pay for these contracts, the original bond issue proved only sufficient for constructing the works down to the district line, so that a further issue became necessary if the district was to construct the distribution system within the district. Accordingly, an election was held January 25, 1913, at which were submitted two propositions: One for the issuance of bonds amounting to $1,170,000.00 for construction and completion of the main distributory canal within the district and for laterals and drainage ditches, the distribution system to extend to each 40-acre tract within the district; the other for the issuance of bonds amounting to $790,000.00 for the construction of a foothill reservoir and other storage facilities. There was much discussion in the district prior to this bond election as to the desirability of completing the distributing system of the district to each 40-acre tract, which was something no other irrigation district in the state had done. The proposition to do this was, however, submitted and carried by a vote of 492 to 24, the proposal to issue bonds for reservoir construction carrying by 432 to 83.

After the early difficulty experienced by the district in disposing of its bonds except through contractors, the estimates of the engineer of the district covering construction of the distribution system and of the proposed storage were based on selling the bonds at a figure considerably below par. There was still some difficulty, however, in obtaining contracts within the estimates, and it was necessary to levy a special assessment of $140,000.00 in 1914 to complete the work. So determined were the people of the district that the system should be completed as planned, that when the matter was laid tentatively before them, they not only consented to this assessment, but pledged themselves to the amount of over $20,000.00 pending the calling of the special election, in order that the construction work should go on without delay. Rights

PLATE V.

Fig. 1.—Goodwin Dam of Oakdale and South San Joaquin Irrigation Districts at low water stage.

Fig. 2.—Headworks of South San Joaquin Irrigation District Canal and portion of Goodwin Dam.

PLATE VI.

Sketch map showing distributing system of South San Joaquin Irrigation District.

Bul. 2—(plate v)

of way were given without cost to the district for all laterals within the district and the distribution system was carried to completion by the early summer of 1914, when the delivery of water began, the upper works having been formally opened April 6th of the previous year.[1]

Although bonds for reservoir construction were voted by South San Joaquin district in 1913, only a small portion of these have thus far been used. Land in the proposed foothill reservoir site has been purchased at a cost of about $87,000.00 and the matter of going ahead with construction is now under consideration. The estimates for completing the distributing system for which $1,170,000.00 was voted along with the reservoir issue included an item of about $85,000.00 for drainage, but this has not yet been constructed. Certain portions of the district are in need of drainage but a complete plan of drainage has not yet been worked out or adopted. The first step contemplated is the construction of an intersecting ditch line along the western boundary of the district to receive waste from the lateral system and also to carry away surplus ground waters in that section.

Counting the three bond issues thus far authorized the total indebtedness in South San Joaquin district is $54.75 per acre, which is the highest cost of any of the California irrigation districts. It must be borne in mind, however, that this cost includes a distributing system to each 40 acres of land within the district (Plate VI), and also a substantial appropriation for storage. It yet remains to be seen whether the complete construction of the distribution system will work out to the advantage of the district, although no one has seriously questioned the judgment of the directors and the people of the district in incurring this expense in advance of closer settlement. Three principal considerations actuated the construction of the distribution system, namely: The probable reduced cost to the community if the laterals should be constructed at one time under a single distribution; the saving in cost of rights of way, these all having been granted free to the district; and the desirability of making water immediately available to each subdivision in the district to the end that settlement might be rapid. It has been the history of the neighboring districts that development of considerable areas has been held back by distance to the main distribution system. While this condition is not of great importance where the acre cost of the irrigation system is low, the question of making water available to each tract at once is a matter of much importance where the cost per acre is as high as in South San Joaquin district. Unfortunately, South San Joaquin irrigation district is most in need of settlers in the period of western development when settlers are scarce.

[1]For description of South San Joaquin irrigation district, including works, soils, and finances, see report of Irrigation District Bond Commission of California, dated May 13 and September 17, 1913, published by the district.

A considerable proportion of the district has been laid out in subdivisions, but these have not yet in large measure been sold. Nevertheless, there are relatively few large holdings in the district, and due to the general rise of ground water and the resulting subirrigation of some of the land, much of the district that is not yet surface irrigated is successfully growing such annual crops as sunflowers, sorghums, sugar beets, and melons, and all of these are returning a higher profit than the former dry-grain farming. Thus the growth of these crops on subirrigated land has changed a condition which might have been considered a serious one to one which is generally considered entirely hopeful. During the season of 1914 application was made to the district for water for 15,600 acres. Preliminary figures available in September, 1915, indicate that approximately 22,000 acres has been irrigated during this season, of which 10,928 acres is in alfalfa, 1,123 acres in trees, 3,136 acres in vines, 1,547 acres in sunflowers, 1,322 acres in beans, 2,909 acres in corn, and 1,224 acres in truck.

Of the 70,050 acres in the district, nearly all was under cultivation when the district was formed, and only 250 acres was classed as untillable. The estimated population of the district in 1915 is 3,500 and the total 1915 valuation assessed for district purposes is $5,478,594.30. The amounts raised annually by assessment have increased from $67,129.69 in 1910 to $372,531.95 in 1914. The irrigation district tax rate per $100.00 valuation has increased from $2.35 in 1910 to $4.85 in 1915. With the exception of between 3,000 and 4,000 acres situated too high to receive water from the system by gravity, which is assessed at $15.00 per acre, the district valuations range from $105.00 down to $80.00 per acre. A zone system, with the towns of Manteca, Ripon, and Escalon as centers, is followed in arriving at valuations. Town lands are valued somewhat arbitrarily, but in general at about one-third of their market value, acreage property within the towns being assessed at $105.00 per acre. In arranging the zones, four squares are described around the towns at distances of one-fourth mile, one-fourth mile, one-half mile, and one-half mile, respectively, from the outside limits of the towns, and the valuations within these four zones range from $100.00 down to $85.00 per acre. All land outside of the last zone and in excess of one and one-half miles from the town limits is valued at $80.00 per acre. While the cost of water in South San Joaquin district is high as compared with other irrigation districts in the state, it is not greater than under some of the other projects, and the general fertility of the soil of the district and the proximity to several main lines of transportation would seem to make the annual charge a somewhat less burden than the same charge would be in a less favorably situated section.

The directors of South San Joaquin district follow the practice of devoting much attention to the management of the district business,

each member of the board having served an average of seventeen days per month during the past six months. While this excessive amount of time is partly due to the fact that some of the members have but recently been elected, nevertheless it seems to be the policy of the board to devote much time to details, rather than to leave these details to the trained engineer employed.

OAKDALE.

The area watered by the old Tulloch system mentioned above in connection with South San Joaquin irrigation district included land around Oakdale, and when South San Joaquin district was successfully organized the people about Oakdale concluded that if nothing were done by them to increase their irrigated area they would be in danger of losing to the South San Joaquin sections water rights still available in Stanislaus River. Thus stimulated, the community was not long in organizing, and within six months from the time the matter was first given publicity, namely, on October 23, 1909, the organization of the Oakdale district was authorized by a vote of 348 to 27. Within a short time thereafter engineers were in the field and a system was laid out calling for the expenditure of $1,600,000.00. A contract was then entered into with the Tulloch interests to purchase those interests for $650,000.00 in bonds, with an agreement that South San Joaquin district should participate in the contract on equal terms with Oakdale. The bond issue of $1,600,000.00 recommended by the engineers was approved by the electors on February 26, 1910, by a vote of 339 to 9. In conjunction with South San Joaquin district the contract with the Tulloch interests was then closed, each district paying $325,000.00 in bonds for a one-half interest in the system, including water rights. The plan of works decided upon was soon adopted, but for nearly two years the district failed to dispose of its bonds, although one bid was accepted and a contract let for a portion of the work, both of which it was later found necessary to cancel. On January 4, 1912, however, contracts were let for the construction of the system, arrangements having been made by the contractors to purchase the bonds of the district at par, as needed. Oakdale district experienced the same difficulty that was experienced in South San Joaquin district in building its works within the estimates of the engineers, on account of the extra price needed to be paid for work under conditions that required the contractors to find purchasers for the bonds. Because of this and other reasons, additional bond issues became necessary, and $400,000.00 were authorized by a vote of 322 to 40 on December 27, 1912, and an additional $400,000.00 by vote of 492 to 129 on October 5, 1914. Construction work under the last issue is now under way and chiefly consists of extensions to laterals,

structures, concrete lining, the elimination of a bad section of canal by the construction of a tunnel estimated to cost $50,000.00, pipes and siphons, and culverts and bridges. The last bond issue of $400,000.00, which bears 6 per cent interest, was disposed of for cash at 90.25, the bidder agreeing to supply the money at stated intervals. The work under all of the bond issues was approved by the state bonding commission, and it is expected that the physical properties of the district will be in excellent shape after the completion of the works now under way. No bonds, however, have yet been voted for storage, nor have definite storage plans yet been adopted. Filings have been made jointly with South San Joaquin irrigation district and the Utica Mining Company for a reservoir at Spicer Meadows in the mountains above Oakdale. There have also been some negotiations regarding storage between Oakdale and South San Joaquin districts and the San Francisco and Sierra Power Company, which also has power interests on the Stanislaus.[1]

Including land irrigated under contracts taken over from the Tulloch system, Oakdale irrigation district irrigated a total of 11,217 acres in 1914, of which 5,017 acres was in alfalfa, 538 acres in garden, 1,109 acres in trees, 77 acres in berries, 132 acres in vines, 25 acres in beets, 1,698 acres in beans, 27 acres in melons, 1,882 acres in corn, 512 acres of new land being flooded for leveling, and 200 acres in rice. No definite unit has been fixed upon to which district laterals will be constructed, but the main and subsidiary laterals of the district are being extended to bring water within relatively easy access to landowners. The total area embraced in Oakdale district is 74,146 acres.

According to the assessment roll of 1914, there were in the district in that year forty-five holdings of 400 acres or over, and nine holdings exceeding 1,000 acres. On the other hand, there were many small units—112 of five acres each, 158 of ten acres each, 127 of twenty acres each, 45 of thirty acres each, 56 of forty acres each, and 22 of fifty acres each. Approximately forty-five subdivisions have been laid out in which the prevailing unit is forty acres, but these have not yet been largely sold. The largest development thus far is in what are locally known as the bench lands lying between Oakdale and the eastern boundary of Modesto irrigation district. East and southeast of Oakdale the lands are more rolling in character, the district having quite irregular boundaries in order to take in the flat lands among the hills. On the north side of Stanislaus River east of Oakdale, and also in the neighborhood of Oakdale, there was a considerable development in fruit growing, chiefly including citrus fruits and almonds, prior to the forma-

[1]For a general description of Oakdale irrigation district, including soils, works, financial conditions, etc., *see* report on Oakdale irrigation district by the State Irrigation District Bond Commission, dated June 25, 1914, and published by the California State Printing Office.

tion of the district. In the bottom lands in the immediate vicinity of Oakdale, vegetable growing has been very successful. Water was first delivered through the new works of the district in 1914.

Valuations assessed for district purposes by Oakdale district have increased from $2,160,355.00 in 1910, to $3,342,140.00 in 1914. The district tax rate in 1910 was $2.62 on each $100.00 of valuation, and it has recently been fixed at $5.80 for 1915. Owing to the irregular character of the lands in Oakdale district, it was found impracticable to apply a zone system in making valuations. Acreage property in the town of Oakdale is assessed at $110.00 per acre; river bottom lands at $90.00 per acre; acreage property in towns other than Oakdale at $50.00 to $70.00 per acre; farm lands immediately surrounding Oakdale at $90.00 per acre; lands in the Orange Blossom citrus section at $60.00 per acre; the bench farming lands next below the rolling plains at about $60.00 per acre; and the rolling plains lands generally at $45.00 per acre. Some nonagricultural land along the river beds is assessed nominally and land above the ditch too high to receive water by gravity at $10.00 per acre.

The organization of Oakdale irrigation district has already had an appreciable effect in increasing population, in spite of the fact that as in South San Joaquin irrigation district and nearly all other irrigation projects in the west, settlement has been very slow during the past two years. The estimated population at the time the district was organized was 2,000, but this is now considered by the district assessors to have increased to 6,000. The first assessment roll of the district in 1910 had 703 assessment payers, but this had increased to 1,505 in 1915. As in the case of South San Joaquin district, Oakdale district receives some water well into the fall, due to the operation of power companies above Oakdale. While this supply will not be large until storage is provided by the districts, it is now sufficient to give late water to the crops most in need of it.

Internal affairs have not always run smoothly in Oakdale district, although there have been no greater internal difficulties than in most other new projects. When the third bond issue was found necessary, there was some dissatisfaction among certain of the people and an unsuccessful effort was made to recall the entire board of directors. Although they have employed a competent and experienced chief engineer and general manager, the members of the board of directors in some cases still devote a considerable amount of time to the details of district management, a majority of the members spending about ten days per month each on the district business, and one usually spending from twenty to twenty-five days per month. The board keeps a standing field committee of three members, one of whom is changed each month.

WATERFORD.

Approximately 13,000 acres are included in this district, which adjoins Modesto irrigation district on the west, and Oakdale irrigation district on the north. The lands embraced are generally those lying between Dry Creek and Tuolumne River, and extending from the western boundary of Modesto district eastward to the Modesto irrigation district reservoir at Dallas Lake. Some of the bottom lands along Tuolumne River east of Dallas Lake, and some of the bench lands lying directly north of them, are also included.

Waterford district was organized by a vote of 70 to 1 on September 6, 1913, and steps were immediately taken to make necessary surveys and to outline a system of works. Both Tuolumne and Stanislaus rivers were considered as sources and the former determined upon. It was realized, however, that on account of prior appropriations on the river by Modesto and Turlock irrigation districts, and by the city of San Francisco for a municipal supply, as well as by power companies, the chief dependence must be placed on storage. This it proposes to acquire through cooperation with Modesto and Turlock districts in the construction of the contemplated reservoir in Tuolumne River about six miles above La Grange dam. Water is now available to Waterford district without storage during the flood periods of the late spring and early summer, and the district is now seeking to acquire a right to divert water through Modesto canal by enlarging that canal down to the Waterford district lands. [1]At one time it was proposed to petition Modesto irrigation district for the inclusion in that district of all the land of the Waterford district, but this plan has been abandoned. The best method of combining the works of the two districts and the proper cost to be borne by Waterford district have been under discussion for some months, but in order to reach a conclusion most easily, it is now proposed for Waterford district to bring suit for condemnation of a right of way through Modesto canal, as permitted by an amendment to the Code of Civil Procedure passed at the last session of the California legislature.[2] In connection with this condemnation suit is is proposed to ask the State Railroad Commission to fix the price to be paid by Waterford district.

Land included in Waterford district is very similar to that in Oakdale district, and is really a continuation of it. For years the area included was a very satisfactory grain producing section, and most of the land in the district is now dry-cultivated for that crop. There are

[1]This right has since been acquired at a cost of $254,000.00, which includes both an interest in La Grange Dam and an interest in the enlarged works necessary.

[2]Statutes 1915, chapter 429. Among other things, this chapter amends section 1240 of the Code of Civil Procedure by providing that property appropriated to one public use by any irrigation district may be taken by another irrigation district for another public use for a purpose not inconsistent with existing purposes and use, this to include the right to enlarge, change, or improve the property to be taken.

about 150 assessment payers in the district, about 6,000 acres out of the total 13,000 acres included, however, being the property of one individual. Final estimates of cost have not been made, but it is hoped to bring the cost per acre within $30.00, exclusive of reservoir construction. If there is no delay in the proceedings now under way, it is expected that some water will be available through Modesto canal during the high water period of 1916.

MODESTO.[1]

As detailed in the history of Modesto irrigation district, previously given, irrigation water first became available for general use in this district in the early spring of 1904. During that year Modesto canal carried a mean flow of 167 and a maximum flow of 278 cubic feet per second and supplied water to 6,895 acres. The maximum diversion during the season of 1915 has been 730 cubic feet per second and, according to estimates supplied to the superintendent of the district at the beginning of the irrigation season of 1915, the total area for which water applications were filed with the district for the season of 1915 was 51,915 acres.[2] In 1904 the number of assessment payers in the district was 1,053, the assessed valuation was $4,342,125.00, and the total irrigation district tax was $112,895.25. In 1914 the number of assessment payers had increased to 2,912, the assessed valuation to $6,961,245.00, and the total tax, which was even larger in 1911 and 1913, to $174,031.13. The bonded indebtedness of the district in 1904 was $1,388,511.00, or $17.10 for each of the 81,143 acres in the district. On December 31, 1914, the outstanding bonded indebtedness was $1,605,823.75, to which has since been added the fifth and sixth issues, dated July 1, 1914, amounting to $610,000.00, making a total of $2,215,823.75, or an average of $27.30 per acre. With the exception of the years 1907, 1911, and 1913, when extra large special assessments were levied for improvements, this increase has been accomplished with no addition to, and sometimes with even a slight reduction of, the irrigation district tax rate. During these eleven years the minimum tax rate has been $2.30 and the maximum $3.75 per $100.00 of assessed valuation. For the past ten years the special assessments for betterments have ranged from $25,000.00 to $75,000.00 per annum, and have averaged about $40,000.00.

The succeeding account of the present status of Turlock irrigation district tells something of the difficulties that have arisen in the adjustment of the farmers of that district to the practice of irrigation. Conditions in Modesto district have been very similar, and the result in

[1] For additional data on the present status of Modesto irrigation district, see report on this district by the Irrigation District Bond Commission of California, dated June 25, 1914. California State Printing Office, 1914.

[2] This area was distributed among the following crops: Alfalfa, 41,663 acres; trees, 2,867 acres; vines, 1,515 acres; beans, 1,815 acres; corn, 843 acres; grain, 3,076 acres; garden, 136 acres.

Modesto district, as in Turlock district, has finally been a better and broader outlook on the part of the farmers, and a definite tendency toward improved standards of management. How to improve and enlarge the district works, the amount of storage needed, and how best to get it, the proper division of the district into electoral divisions in order to minimize what some considered undue control by the voters in the city of Modesto, methods and efficiency of water distribution, who should be the engineer and superintendent and what should be his authority, and the attitude the district should assume toward diversions from the Tuolumne River watershed by the city of San Francisco, have been among the problems that have caused controversy. Regardless of whether these matters have been rightly or wrongly settled, the district has made, and is making, a definite and commendable advance, and is now engaged in a type of permanent betterments that must stand as a credit to the community.

In 1904 there were 8,932 lineal feet of wooden flumes and thirteen large wooden structures on the main Modesto canal. When work now under way is completed all of the wooden flumes and most of the drops will have been eliminated and permanent construction substituted. This permanent construction, which began in 1904, and has been continued as means would permit each year since then, has also included, among other improvements, the rebuilding of part of the headgate at La Grange dam, a large amount of concrete lining near the upper works, hydraulic fills with concrete-lined channels at the upper and lower Dominici and the Morton gulch crossings, the construction of Dallas and Warner foothill reservoirs, at a cost to date of approximately $260,000.00, enlargement of a portion of the main canal above the reservoirs to a carrying capacity of 2,000 cubic feet per second, and a beginning on a drainage system in the district. Work now under way, which is being paid for from the proceeds of the fifth and sixth bond issues, bearing 6 per cent interest, of which $25,000.00 was sold at par to the state and $585,000.00 sold for cash through a bond broker at 90.6, includes construction of hydraulic fills with concrete-lined channels at Indian Hill, Gasburg, Rairdan, and Salter gulch crossings, a reinforced concrete flume and spillway at the Dry Creek crossing, completion of the reconstruction of the headgate at La Grange dam, and the construction of a concrete cut-off wall at the inner toe of the outlet dam at Dallas reservoir and the facing with concrete of dams Nos. 1 and 6 at the same reservoir. When this work is completed it is proposed to spend an additional $35,000.00 in adding to the main open drain system in the district, to line three or four miles of the main canal at dangerous points, to give the main canal a capacity of 2,000 cubic feet per second from La Grange dam to the reservoirs and a capacity of 1,200 cubic feet per second

PLATE VII.

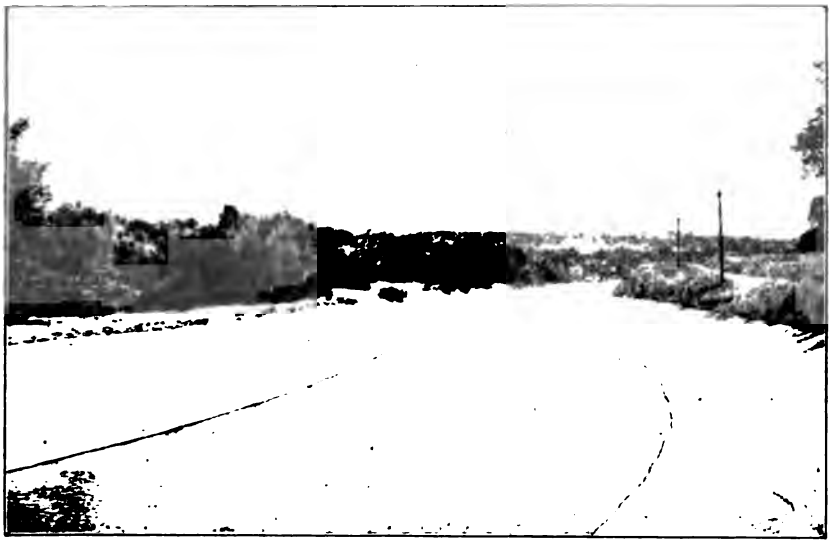

Fig. 1.—Concrete-lined portion of Modesto Canal in foothills below La Grange.

Fig 2.—Hydraulic fill with concrete-lined channel, Modesto Canal.

between the reservoirs and the district line, to build about fifty principal concrete headgates and checks within the district, to replace the four remaining wooden drops in the main canal with permanent concrete structures, and to build permanent wasteways at Waterford and at the lower Dominici fill. The engineer's estimate is that for the completion of the above work about $250,000.00 will be necessary in addition to the $610,000.00 in bonds comprising the fifth and sixth issues. There will then be left to build such additional drainage works as are found to be necessary and such additional reservoirs as it is decided to construct. Plans are now tentatively under way for the construction of a reservoir in the bed of Tuolumne River about six miles above La Grange dam in conjunction with Turlock district. It has recently been proposed to make an endeavor to get federal aid in the construction of this reservoir, it being claimed by the districts that, after having built up their communities entirely through their own efforts, they are now as much entitled to federal aid in reservoir construction as are different reclamation projects in which a very large proportion of the land benefited was in private ownership prior to government construction.

In common with other California irrigation districts, Modesto district has developed its own peculiar plan of levying district assessments. Improvements were exempted from district assessment on June 3, 1911, by vote of 487 to 403. Prior to that time a considerable portion of the total taxes raised came from improvements. Under present conditions the district assessor, in general, raises both farm and city property within the district about 50 per cent above the assessment for county purposes, except that the maximum appraisal per acre for farm land in the district is $90.00, this being the base for appraisal within one mile of the city of Modesto. Around the towns of Salida and Empire the base for appraisal purposes is $85.00. From these two bases of $90.00 and $85.00 assessments grade down to about 50 per cent above the county valuation. Vacant farming lands within the city of Modesto which are held for subdivisional purposes are appraised at from $150.00 to $200.00 per acre. An innovation in the assessment of business lands within the city of Modesto is the addition of about 25 per cent and possibly a little more on such property over the appraisal of town residence property. The question of reducing the assessment on lands too far from the district canals to be served with water has never arisen in Modesto district because the district does not build the distributing laterals other than the main laterals. In some cases, however, the district has taken over private laterals built by others on condition that the irrigators served sign agreements to abide by the rules of the district. For this it has been necessary to employ additional ditchtenders who serve from three to ten days per run at a daily wage of $2.50. In this connection it might be added that the district is drifting toward the plan of complete

district control and supervision of distribution, regardless of lateral owners.

The distribution of water in Modesto district is now under the control of a superintendent and sixteen ditchtenders, the latter receiving $70.00 to $80.00 per month with neither house nor means of conveyance furnished. On the main canal ditchtenders are employed the year around, the others being employed during the irrigation season only, although they are used a portion of the nonirrigating season in general canal maintenance.

The usual irrigating head delivered in Modesto district is 20 cubic feet per second. When the district first started irrigation, methods of preparing land were exceedingly crude, the contour method with high and irregular levees being the most common practice. At present a majority of the irrigators use "gravity" or strip checks from 50 to 150 feet wide and up to one-fourth mile long, with the best practice confined to checks less than 75 feet wide and not over one-eighth mile long.

The directors of Modesto district still devote a good deal of their time to its management, holding regular meetings during construction periods about once per week, with committees of two or three directors devoting about an average of one day per week, in addition, to general supervision. At present the construction and operating forces are entirely separate.

The amendment to the irrigation district act permitting the recall of elective officers in irrigation districts was passed at the instance of people living in Modesto district and recall elections have been resorted to on three occasions, in two of which they were successful. As indicating a more stable feature of the management of this district, however, the interesting fact is worth noting that the very efficient secretary of the district has been kept steadfastly and continuously at his post for the last twenty-four years.

The matter of redivisioning Modesto district in order to place the city of Modesto in a division entirely separated from the divisions embracing the farm lands at one time aroused considerable discussion and was finally carried out. The idea prompting the change was that if embraced within a single electoral division, the voters in Modesto would not be able to control the board of directors as some had charged they had been able to do when the city extended into several of the divisions. The main argument advanced against the redivision was that about one-half of the population of the district resides within the city, and that having its representation upon the board of directors reduced to one out of five, the city population would be unfairly treated.

TURLOCK.[1]

Turlock irrigation district, since its financial reorganization in 1902, and Modesto district, directly across Tuolumne River, since the refunding of its indebtedness, have furnished the most interesting phases of the history of irrigation district operation in California under the amended law of 1897. In no other districts in the state have the provisions of the law been so fully taken advantage of, and in no other districts have the people experienced so fully the personal and social readjustments necessary in a municipal enterprise of the magnitude of these two districts. The latter statement is made with due realization of the fact that internal controversies have occurred even within the past year, and that they are sure to occur in the future, yet in the belief that the net gain in the ability of the communities to deal successfully with the complicated questions involved in the management of the large properties involved has been a definite and a permanent one.

Water was first available in Turlock irrigation district in 1901, in which year it was used on 3,757 acres. Holdings were scattered widely over the district and any satisfactory delivery of water was out of the question. Few in the district had had experience in irrigation, and in their ignorance of their own difficulties and of difficulties of the district officers many expected far more from the district than it was possible for the district to give. The first few years were therefore naturally stormy ones and meetings of dissenters were frequent and often acrimonious. Being wholly unused to the handling of million-dollar corporations, the farmer-directors, always naturally conservative, felt their way with extra caution and hesitated to spend even pennies where dollars were required for efficient administration. In spite of continual agitation there was only slow improvement in the earlier crude conditions for seven or eight years, and neither the first nor the second nor the third superintendent was able to come up to the expectations of the water users. Happily, conditions have greatly changed in Turlock district in the last few years. Although to state that there is no longer any trouble would be far in excess of the truth, nevertheless the better attitude of the people of the district toward its management is not the least of the district's present assets. The harness-shop desk room of the first superintendent, paid for by him, has given way to substantial office quarters on the main street of Turlock owned by the district, where at least the essential needs of both engineering corps and office force are provided. So, also, ample automobile conveyance, furnished by the district, has replaced the slower team conveyance of the first years which the superintendent of the district was expected to supply at his own

[1]For additional data on the present status of Turlock irrigation district, see the report on this district by the Irrigation District Bond Commission of California, dated June 25, 1914. California State Printing Office, 1914.

expense. In place of the almost total absence of any records whatever, either as to the running of water or the physical condition of the system, as in the early years of operation, data are now available in quite complete form for nearly every phase of the district's various activities. The first superintendent had few if any facilities for establishing anything like an equitable distribution of water, either among the various laterals or among the users. He had little knowledge of seepage losses on the system and no means of making measurements. The present engineer has two men with current meters constantly employed in determining losses and aiding in the measurement of water to the various distributaries and in assisting the ditchtenders in maintaining the standard "heads." And now with the data at his command the engineer is able to direct such division of the water as will result in delivering to each ditchtender the amount necessary to give him his pro rata share of the entire supply after allowing for seepage and evaporation losses in transit. By knowing the amount of water, in acre-feet, delivered daily to each ditchtender and by having delivery receipts from each irrigator receiving water the engineer is able to keep a close check on the work of the ditchtenders. While it can not be said that distribution is yet always wholly satisfactory either to the engineer or to all of the irrigators, yet conditions both in the handling of the water and in the reasonableness of the irrigators have so greatly improved that water distribution in Turlock district is no longer a source of constant friction.

The present area of Turlock irrigation district is 175,566 acres, 644 acres having been withdrawn in March, 1911. The number of taxpayers has increased from 400 in 1901 to 5,000 in 1914, and the area irrigated from 3,757 acres in 1901 to 95,698 acres, or about 55 per cent of the total area in the district, in 1915. Along with this increase in the number of taxpayers and the area irrigated there has necessarily come an increase in the extent of the works and in the bonded indebtedness. The total length of canals and main laterals has grown from 135.16 miles in 1900 to 230.57 miles in 1915, not counting about 700 miles of sublaterals; the bonded indebtedness has increased from $1,170,000.00 in 1901 to $2,302,400.00, or $13.11 per acre, at the close of 1914, all bonds except the original funded issue bearing 5 per cent. This increase in bonded indebtedness has raised the tax rate from $2.40 in 1901 to $3.65 in 1914, and the total tax for both bonds and maintenance and operation from $40,766.40 in 1901 to $370,829.89 in 1914. With this increase in tax rate, however, has come an increase in the amount of water run, from a maximum of 535 cubic feet per second in 1904, the first year of keeping records, to a maximum of 1,580 cubic feet per second in 1915. During these years the total assessed valuation within the district has gone up from $1,788,589.00 to $10,165,890.00.

PLATE VIII.

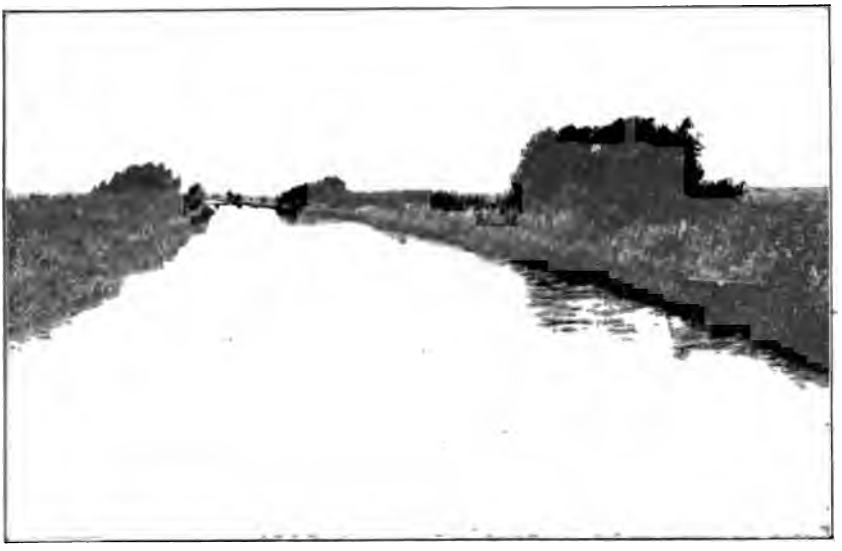

Fig. 1.—Ceres main of Turlock Canal.

Fig. 2.—Typical concrete check with automatic regulating gate, Turlock Irrigation District.

The increased expenditures on capital account since 1901 have been mainly applied to improvements in the upper works, the construction of the Davis foothill reservoir, the construction of new laterals from the old system or the extension of laterals already built, the construction of the high-line canal 28.97 miles long, together with various cross ditches and laterals, and the substitution of permanent for the former temporary structures in different parts of the system. Improvements in the upper works have included new headworks and controlling gates, the elimination of about 900 lineal feet of wooden flumes and the construction in their place of concrete-lined hydraulic fills, the concreting of points in the main canal where seepage was heavy and the banks unsafe, and the reconstruction or the widening and deepening of portions of the main canal above Hickman. Surveys have been made and some preliminary work done and land purchased for an additional reservoir on Tuolumne River about five miles above La Grange, but no provision has yet been made for the cost of construction. Automatic regulating gates have been installed at all principal division points and at many points of minor importance. The present plans of the district, if carried out, will result, in addition to further storage, in completing the enlargement of the main canal to a capacity of 2,000 cubic feet per second from La Grange to Hickman and improving the present distributing system, including the construction of several new laterals necessary to reach land now coming into cultivation and the lining of canals and laterals. The construction of the works of the district and their improvement have not been accomplished without both mistakes and unforeseen difficulties and more than once breaks in the upper works have caused serious damage and not infrequently loss of crops through temporary stopping of the water supply. For an enterprise with such large capital investment and such important construction as Turlock district shows there has undoubtedly been undue conservatism in the employment of special engineering advice, yet the generally satisfactory outcome, both as to acre-costs and character of works, must be considered a definite achievement.

In determining valuations for irrigation district purposes the assessor of Turlock irrigation district is now endeavoring to appraise land at about 50 per cent of its market value. Prior to 1910 it was usual to take the county assessment roll in making up the district assessment roll. In that year the district assessor raised all of the lands $20.00 per acre regardless of their value, which of course resulted in a very much larger percentage of increase on the low-valued lands than on those that were valued high. That arrangement, however, was only temporary, although the present assessor has held to the valuations of $20.00 above the county assessment on average land of the district. The highest valuation placed on any of the farm lands in the district is now

$80.00 per acre. Land too high to receive water from the canals, but which can still be used for dry-farming, is assessed at $15.00. Land that has been swamped by irrigation is valued at $1.00. Land available for suburban subdivision adjoining the city limits of Turlock in some cases runs up to a valuation of $150.00 per acre. Around other towns in the district assessment is entirely on a farm land basis. The assessor is now endeavoring to consider all of the elements that make up market value, as character of soil, proximity to town, etc. Up to 1915 the town property has been given a value slightly below that carried on the county assessment roll, this favoring of the towns having been considered justifiable because of the extra local taxes there for town improvements. Land in all of the towns is carried at the figures given on the county assessment roll, which are estimated to range from 40 to 50 per cent of market value. In 1914 the district voted to exempt improvements from irrigation district taxes.

Turlock irrigation district has tried various methods of supervising water distribution and delivery. At first both maintenance and operation and all engineering work were in the hands of the engineer and superintendent. Later a superintendent of water delivery was placed directly under the board and the duties of the engineer were confined to engineering matters. There has recently been a demand for putting the entire responsibility for engineering and distribution in the hands of a single official and that plan is now followed, an assistant engineer attending to water delivery under the direction of the chief engineer. Water delivery records are kept in both field and office. In January each ditchtender goes over his entire division and receives from each irrigator applications for water for the pending season, specifying the acreage of each crop to be irrigated. These applications are copied in alphabetical order into a book in the district office and form a permanent record. There is also kept in the office a typewritten list of the irrigators under each ditchtender, arranged in the order in which they are to receive water, and showing the number of acres each is to irrigate. Gauges are installed at the point each ditchtender receives his supply from the main canal and also at each point of delivery. All land is irrigated in rotation, beginning at the lower end of the canals, the average alfalfa "head" being 20 cubic feet per second measured at heads of private ditches and the time allowed usually being thirty minutes to the acre which, after allowing for seepage, gives a depth of approximately .60 foot over each acre for each irrigation. Where 10 cubic feet per second is delivered one hour is allowed in order to give the same quantity. This smaller head is called for only for orchard and other furrow irrigation. When there is an abundance of water the time of irrigation is extended on account of high checks or other conditions making distribution difficult. In the delivery of water, receipts are

taken in triplicate from each irrigator, the original being sent to the office at Turlock, one copy being given to the irrigator, and one copy retained by the ditchtender. Private ditches are all maintained by the irrigators who receive water from them. Some of these are in poor condition and where such is the case the district frequently refuses to turn in water until conditions are improved. At present thirty-one ditchtenders are employed, mostly at the rate of $75.00 per month, and their time for eight months is charged to operation and for four months to maintenance. A machine shop is maintained with a machinist at $100.00 per month, a blacksmith at $3.50 per day, and a helper at $2.50 per day. There is also maintained a repair camp with a foreman at $90.00 per month, two helpers at $72.50 per month, a cook at $45.00 per month, and eight day employees at wages ranging from $2.25 to $3.00; also a ditch maintenance camp with a foreman at $75.00 per month, and fifteen teamsters, helpers, laborers, and carpenters at wages ranging from $2.25 per day to $50.00 per month. The expense of the repair camp is charged to maintenance and operation for eight months and to new work for four months each year, and that of the ditch maintenance camp to maintenance and operation for four months and to new work for eight months. The cost of superintendence of maintenance and operation, including all measurement of water, is $600.00 per month for eight months each year. The general office force at Turlock consists of the secretary at $100.00 per month, bookkeeper at $100.00 per month, assessor-collector-treasurer at $175.00 per month, and clerical and other help at a total of $115.00 per month.

Alfalfa is still the principal irrigated crop in Turlock district, the acreage devoted to it in 1915 being 64,558 acres. Other crops and acreages are: vines, 3,208 acres; trees, 4,722 acres; garden, 837 acres; corn, 5,870 acres; beans, 863 acres; sweet potatoes, 3,151 acres; melons, 3,840 acres; grain, 5,594 acres; miscellaneous, 1,660 acres; berries, 9 acres; new land, 743 acres; nursery, 643 acres.

In recent years it has been the policy of the board of directors of Turlock district personally to give a great deal of their attention to the physical properties of the district. For this purpose they have met frequently and have frequently gone over the district works, especially during reconstruction and important repairs. The law allows directors a per diem of $4.00 for each day devoted to the affairs of the district. The total amount received by them in fees in 1914 amounted to approximately $2,500.00, indicating that on the average each director devoted about 125 days to district affairs during the year. It is estimated that during 1915, however, each director will average only about three or four days per month. At present the directors work largely through standing committees which change frequently in order to keep the various members of the board in close touch with district affairs.

Except in one or two instances, it is believed that the boards of directors of the district have worked harmoniously together, yet there has been some local public criticism of the policy of the board under which its members frequently undertake to determine matters about which only the engineer of the district, or better, a consulting engineering specialist, is best able to judge. Out of this situation there has grown up a considerable sentiment in favor of the employment of a district general manager with whom final responsibility should be lodged. The recall has been employed in Turlock district on only two occasions, and then against individual members of the board of directors. In each case it was unsuccessful, the incumbents being retained by substantial majorities.

ALTA.

This district is the third largest in California, with 130,000 acres. Although during the hard years following the early nineties and prior to the bond settlement and refunding in 1901 and 1902 it was in poor financial condition, it has never ceased activity since organization in 1888, and is now in a generally prosperous condition. Old wooden structures are gradually being replaced with concrete, the cost of this being paid from annual assessments for maintenance, operation, and betterments. Work of this character done since the bond settlement in 1901 and 1902 has included a new main headgate of reinforced concrete in Kings River, costing about $9,000.00; a light concrete dam 96 feet long at Wahtoke Creek, costing only about $250.00; 1,500 lineal feet of 4-inch concrete lining in the main canal at Dunnigan Gap where the canal is 50 feet wide on the bottom, costing about $9,000.00; about 250 concrete drops replacing wooden structures and costing from $100.00 to $500.00 each; a concrete flume across Sand Creek, costing about $500.00, and the lining of sections in a number of laterals. In all it is estimated by the superintendent that two-thirds of the wooden structures on the main laterals have been replaced with concrete. The system is in such shape now that 1,300 cubic feet of water per second can be carried and distributed whenever that amount is available from the river and is wanted by the irrigators.

Irrigation practice in Alta irrigation district is still very wasteful. No measurements are made to irrigators and except in very dry years they are given whatever water they want. As a rule, the land has not been well prepared. Usually both orchards and vineyards, which together make up more than one-fourth of the crops grown, are irrigated, and most generally by various methods of basin flooding, the application of as much as 1.5 to 2 feet in depth per irrigation being not at all uncommon. Several thousand acres in the district are still in grain, but this is not irrigated much now. About 15 per cent of the

farms now have pumping plants to supplement gravity irrigation, when the Kings River supply gives out, as it usually does by July. No steps have been yet taken by the district to provide drainage, which is still needed in parts of the district. No ground water records have been kept, but the superintendent of the district states that in the dry years of 1913 and 1914 the water table lowered in sections about four feet. About Reedley it now stands at ten to twenty feet below the surface in the fall of the year, according to information furnished by the superintendent, and at five to seven feet below the surface about Dinuba. In the southwestern portion of the district it is generally higher, especially when water is being run.

Alta irrigation district is operated at a relatively low cost. Assessments for operation, maintenance, and betterments since 1910 have ranged from $27,500.00 to $35,000.00, or not over an average of 25 cents per acre per year. Valuations of farm properties for district assessment purposes have with a few variations ranged from $30.00 per acre for the best lands down through successive and somewhat arbitrary grades of $27.50, $25.00, $20.00, $15.00, $12.50, $10.00, $7.50, $5.00, $3.00, and $2.50, the two lowest valuations being for some alkali lands in the two southern divisions. Land of good quality lying adjacent to the canals, but just too high to receive water by gravity, is valued at $10.00 to $20.00 on the ground that it is benefited by subirrigation. Improvements on farm properties are assessed in about the same ratio. All of the several towns of the district, including Dinuba, Reedley, and Traver, are within the legal boundaries. Lot valuations range from $20.00 to $60.00 for a 20-foot by 150-foot lot, exclusive of improvements, the latter being added at about 20 per cent of their cash value. In the district assessment of 1914 town lots were given a total value of $128,504.00; improvements on town lots, $204,505.00; real estate other than town lots, $2,348,733.00; improvements thereon, $356,965.00; miscellaneous properties, $6,000.00; total, $3,044,707.00. It will be noted that town properties carry about 11 per cent of the total district tax. The assessor of the district, individually or through deputies, visits each tract in the district for district assessment purposes yearly and requires an individual declaration from each property holder, as in the case of city and county general assessments in California. Alta is the only irrigation district visited in which this practice is followed.

The operation of Alta irrigation district has resulted in greatly reducing the size of land holdings and in increasing the number of district taxpayers from about 800 in 1895 to about 3,100 in 1914. There are now more holdings of 20 acres than of any other size, many of 40 acres, a few of 160 acres and under 320 acres, and an occasional half-section. Originally there were many full sections in the district and some holdings of several sections.

The salaried force of Alta district is modestly paid, the superintendent receiving $1,500.00, the assessor $800.00, the collector $800.00, the secretary $600.00, and the treasurer a nominal salary only. While the board of directors hold the usual monthly meetings and confer with the superintendent, and occasionally send out a committee of one or two board members to make special observations, the management of the physical properties of the district is left almost wholly to the superintendent. No delivery records are kept and, as already stated, no measurements are made to irrigators. At present the delivery force under the superintendent consists of seventeen men, each of whom receives $75.00 per month for six to seven months yearly as ditchtenders, and day wages at other times during the year when their services can be used in repair work and canal cleaning. The district builds and maintains all gates on canals and laterals situated on rights of way owned by the district.

Although the funding bonds issued by Alta district in 1902 do not begin falling due until 1921, bonds to the value of $41,500.00 have already been redeemed from surplus interest assessments, 68 having been taken at .932 and the remaining 15 at from .896 to .95. It is the policy of the district to reduce bonds whenever there is a surplus in the bond fund of $5,000.00 or $6,000.00. The present bonded indebtedness is $451,000.00, or at the rate of only $3.47 per acre. No bonds have been issued since the funding bonds of 1902.

TULARE.

The community served by Tulare district has made definite progress since its bond settlement in 1903, and there has been a considerable improvement of the irrigation systems. As an organization, however, Tulare district has not advanced materially. So severe was the lesson of the old bond indebtedness that since that was wiped off and the bonds burned the community has been very much averse to using the taxing power of the district law. With the exception of one assessment of $10,000.00 in 1909 for betterments, none has been levied since the settlement, the entire cost of maintenance and operation and of some minor betterments having been met from water tolls. Owing to the wide fluctuation in the amount of water used each year, which is dependent on the supply available to the district from Kaweah and St. Johns rivers, the amount raised from tolls has also fluctuated. The smallest annual income of record was that of 1913 when only about 100 acres was watered and only $141.75 received from tolls. The largest area ever irrigated is estimated by the superintendent at 15,000 acres. Eliminating the year 1913 above referred to, the total tolls from 1909 to 1914 have ranged from $2,981.85 in 1912 to $10,475.20 in 1911. It is estimated by the superintendent that about 6,000 acres will be

PLATE IX.

Fig. 1.—Alta Irrigation District Canal near Wahtoke Lake.

Fig. 2.—Typical orchard irrigation in Alta Irrigation District. (Note excessive use of water.)

watered in 1915. The tolls charged for water are usually $1.50 per acre for the first irrigation and $1.00 per acre for each subsequent irrigation, although they have in times past been as low as 50 cents per acre per irrigation.

The improvements made in the works of Tulare irrigation district have not involved any large expenditures. A concrete siphon 300 feet long under Kaweah River, with a claimed capacity under an 8-foot head of 300 cubic feet per second, cost $3,200.00. Most of the wooden check gates in the canals above Tulare have been replaced by concrete checks at an average cost estimated by the superintendent at $250.00. A concrete structure at the Cameron Creek crossing of the main canal, so built as to permit the passage of Cameron Creek when so desired, involved an expenditure of $1,500.00. Other improvements, with approximate costs when known, have been as follows: Raising and repairing of dam at the St. Johns River intake, about $300.00; wasteway one-quarter mile below the dam, about $250.00; repairs to span at St. Johns River crossing, about $700.00; replacing of second span at St. Johns crossing; new wooden delivery headgates. In addition to these improvements, twelve acres have been purchased for a right of way in Cameron Creek at a cost of $2,500.00.

The original area included in Tulare district was 39,360 acres, but some lands have been excluded since organization and the exact present area is not known by the district officers, but it is still probably in excess of 35,000 acres. The city of Tulare, covering about three full sections, was taken out in 1911 and about 750 acres was taken out two years later.

The principal irrigated crop in Tulare district is still alfalfa. As a rule orchards and vineyards, due to the availability of ground water, are irrigated only in the drier years. Grain crops are not watered, but after harvesting the grain many irrigate the land and plant Kaffir or Jerusalem corn. The district has no storage reservoir and, as a rule, the water available after satisfying prior rights runs out by July 15th. After that, however, pumping from underground sources is resorted to, a large majority of the farmers having installed pumping plants in the dry years 1912 and 1913 if they had not already done so before. These pumping plants have done much both to improve the available water supply and to reduce danger from the rise of ground water. Most farmers in the district irrigate only once from the district canals, except that when the season makes it desirable to irrigate as early as March, a second irrigation is called for. Rarely a third irrigation from the canal system is practiced.

The irrigation system of Tulare irrigation district is operated very economically. The superintendent, receiving $125.00 per month, and the secretary, who furnishes the district office quarters, receiving $35.00 per month, are the only members of the force who are continuously

employed. One headgate man is given a house and his provisions and a salary of $65.00 per month for about six months each year. Three ditchtenders are usually employed during the irrigation season at $2.50 per day, each ditchtender furnishing and maintaining his own conveyance. During the nonoperating season such help is employed as is needed to do whatever work money is available for, this amount, as already indicated, depending on the quantity of water available during the months irrigators want it. Water is delivered in rotation, commencing at the upper end of the various delivery divisions, except that no water is delivered except as paid for in advance at the office of the secretary of the district in Tulare. On receiving application and payment for water the secretary issues a written order on a special printed form and this reaches the proper ditchtender through the superintendent, all ditchtenders reporting in person to the superintendent in the district office daily and at other times by telephone. The district canal system carries from 300 to 350 cubic feet per second and the usual delivery head is ten cubic feet per second, each user being allowed to retain the water as long as desired. Usually irrigators are given as much water as their ditches can carry. As a result of the lack of restrictions in delivery the use of water is very ununiform and generally wasteful. The district builds and maintains all gates and checks on the main canal and on all distributing laterals, exclusive of those on farms. The management of the system is, in practice, entirely in the hands of the superintendent, the members of the board of directors giving very little attention to it, and knowing little of its physical condition. It is said that there are never any contests for places on the directorate.

In connection with the management of Tulare irrigation district it should be noted that, because all maintenance and operation expenses are paid from water tolls collected only from those who use water from the canals, the landowners in the district who do not irrigate from the district system pay nothing toward its maintenance or toward the maintenance of the water supply in which all have a share. In other words, although all in the district have a right to receive water from the district, they pay nothing for the privilege unless they use water from the canals.

ALPAUGH.

This district was organized March 22, 1915, after consideration extending over several years. The land embraced is the principal portion of Alpaugh Colony and is located in Tulare County on a slightly raised portion of the old bed of Tulare Lake. Alpaugh Colony was established in 1906 by a colonization company that had purchased about 9,000 acres of land situated seven miles southwest of Angiola.

PLATE X.

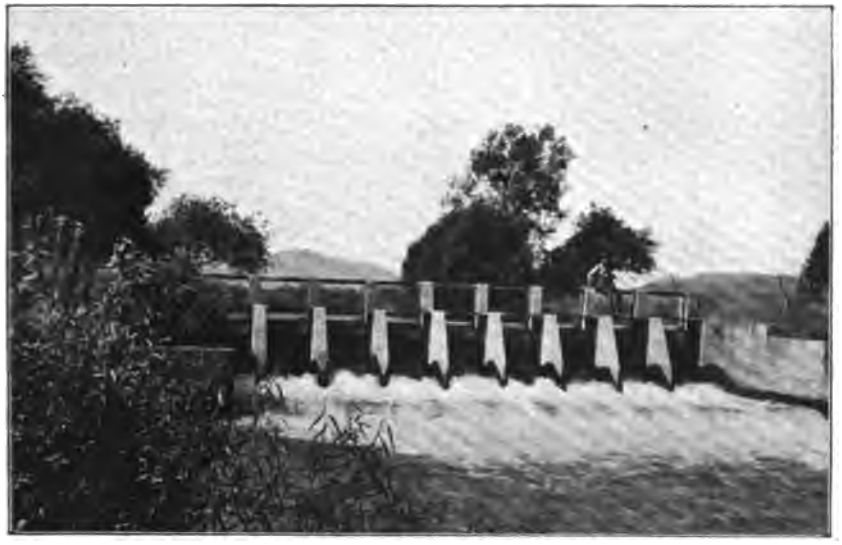

Fig. 1.—Concrete spill and crossing, Alta Irrigation District Canal.

Fig. 2.—Cameron Creek crossing, Tulare Irrigation District Canal.

The land in this colony was sold to the settlers at $19.00 per acre, each acre carrying one share in the Second Extension Water Company, for which $6.00 additional was charged. The agreement under which the colony was established provided that, through the Second Extension Water Company, water should be furnished the settlers at the rate of 200 inches for twelve hours once every thirty days for each share of stock held in the water company. The original plan is said to have provided that this water should be developed within the colony. That plan, however, was changed, and instead a supply was developed from a number of flowing wells at Smyrna, in Kern County, 9.5 miles south of the colony. This supply is still used and is reported to amount to about 900 inches in the winter months and to from 500 to 600 inches in summer, in both cases measured at the wells. From the wells it is carried to within one mile of Alpaugh through a 12-mile open ditch and at that point is pumped a total height of about seven feet for distribution over the colony. As operated by the Second Extension Water Company, the cost of maintenance and operation is met by frequent assessments on the stock, all stock being liable for these assessments regardless of whether water is used. The usual assessment has been 60 cents per share and this amount was levied five times in 1913 and in 1914, and it is expected that it will be levied five times during 1915. While about 9,000 shares of stock in the water company were sold, only about 7,000 shares are still in good standing, some of the nonresident owners having ceased paying assessments.

Alpaugh irrigation district was organized to take over the property of the Second Extension Water Company, the election on organization having been carried by a vote of 71 to 14. At a previous election, on August 26, 1914, 53 votes were cast in favor of the district and 22 votes against it, but as there were 13 additional votes cast for officers of the district which were not marked for or against the district organization, it was held that the 53 votes cast in favor of the organization did not constitute the required two-thirds of the total vote and the election was declared lost.

The purpose of the organization of Alpaugh district has not been merely to substitute an irrigation district for a mutual water company for operating purposes, but in order to finance improvements. The supply now being obtained from Smyrna is inadequate for the needs of the colony, largely because of being conveyed in an open canal in which seepage losses are heavy and in which tule growth greatly reduces the flow. This canal varies in width from 25 to 45 feet and the grade is only about one foot per mile. Plans for improving and enlarging the

water system have not yet been settled upon by the district.[1] The petition for organization specified that the water supply was to be obtained from wells already sunk or to be sunk in sections 23, 26, and 27, township 25 south, range 23 east, and from other wells in that vicinity and in the district. It is locally hoped that a supply can be obtained within or near the district in order to avoid the long carriage from Smyrna. If the Smyrna supply is continued it is proposed to cement the canal. The district has already spent about $1,000.00 in surveys and other preliminary expenses, having raised the necessary money for this purpose by issuing seven per cent warrants, which were taken over by a Visalia bank and discounted to bring the bank eight per cent. When the engineering plans are completed they will be submitted to the State Department of Engineering and if approved will be the basis of a bond issue. As the district proposes to build a first-class distributing system, as well as to increase the water supply, it is expected that the cost per acre will approach $30.00 to $40.00.

The irrigated area in Alpaugh irrigation district is now something over 2,500 acres, of which about 1,500 acres are in alfalfa, about 300 acres in seeds, and the rest in sugar beets and grain. The assessed valuation of the district according to the county assessment roll of 1914 was $111,837.00. The petition for organizing the district carried 182 names which, it is said, represented about two-thirds of the property owners and about two-thirds of the total value of the land. In laying out the district an attempt was made to keep the land within the district in a solid block, but since organization several holdings have been eliminated. The town of Alpaugh is not included.

Alpaugh irrigation district was not formed without considerable opposition. During the campaign for the district a number of printed pamphlets were issued giving arguments for and against it. The first petition for the formation of irrigation district was circulated in a portion of the colony in 1912 and then dropped in order to eliminate the townsite of Alpaugh. The second petition met further opposition and was also dropped. A third petition was declared inadequate by the board of supervisors because it contained the signatures of those who were then owners of lands in the colony, rather than of those whose names appeared on the previous assessment roll. It is now stated by the officers of the district that in the main those who most actively opposed the formation of the district have since either been won over or moved away. The exclusion of several tracts of land originally in the district also served to eliminate some of the opposition.

[1] Plans have since been adopted and after material modification by the State Department of Engineering have been approved and construction has been largely completed; payments therefor having been made in warrants pending validation of the bonds by the state irrigation district bond commission.

PLATE XI.

Fig. 1.—Reconstructed Main Ditch, Little Rock Creek Irrigation District.

Fig. 2.—Underground distributing system, Little Rock Creek Irrigation District.

LITTLE ROCK CREEK.

Since the financial reorganization of this district during the past four years, physical and agricultural conditions have been greatly improved. The principal ditch from Little Rock Creek has been lined with concrete for the first three miles, and a concrete pipe from 16 to 20 inches in diameter substituted for the remaining distance. Distribution from the main ditch is effected through underground concrete pipes, the principal laterals having been constructed by the district and the farm laterals, so far as yet built, by the landowners. Delivery from the main laterals to the farms is made through concrete boxes of the Azusa type and from the farm laterals through concrete standpipes. These improvements in the irrigation system, except the farm laterals paid for by the landowners, have been made with the $35,000.00 bond issue voted in addition to the $25,000.00 issue used for refunding the old bonds. The saving in seepage losses that has been brought about by the improvements has permitted an extension of the irrigated area, there being between 1,400 and 1,500 acres, mostly in Bartlett pears, under cultivation in the summer of 1915. Most of the land in the district, however, is still owned by nonresidents, and there are several subdivisions, laid out some years ago, which have not been largely used or occupied. Some of the latter and one considerable acreage holding have been going delinquent in the matter of district taxes until there is some discussion of having the areas involved eliminated from the district, if that proves feasible.

On the basis of valuations for district assessment purposes of $30.00 per acre in the upper portion of the district, of $20.00 per acre in the lower portion, and of $10.00 each for lots, the 1914 equalized district assessment for the whole district totaled $77,678.00. With the distributing system now extended to the lower areas they will henceforth be assessed at the same figure as those formerly alone within reach of the water system. The 1914 rate of assessment for bond interest and maintenance and operation was ten cents on the dollar.

A single ditchtender attends to water delivery in the district, working through the irrigation season only. Water is not measured. The cost of delivery has thus far been met entirely by assessments but it is contemplated that a water toll will be added for water pumped after the gravity supply in Little Rock Creek falls off. The source of pumped water is a cienega owned by the district near the head of the main ditch. About forty voters voted at the district election in 1913.

BIG ROCK CREEK.

This was one of the early Wright districts and the essential features of its early history have already been given. In May, 1914, a third movement to colonize the district was begun by a group of Los Angeles socialists who have established there the Llano del Rio Cooperative Colony. This colony and the Mescal Water and Land Company together have purchased about 3,000 acres of land in the district and additional purchases up to about 20,000 acres are contemplated. Nearly all of the land in the district is now said to be patented. At the instance of those back of this movement a new board of directors for the district was appointed by the supervisors of Los Angeles County in 1914, and in February, 1915, a board and other necessary officers were elected by the colonists. Of these officers the president and secretary are the vice president and assistant secretary, respectively, of the colony company, all of the other officers also being members of the colony. Thus the district is merely an adjunct of the colony, it being understood that the officers of the district will conform to the general control exercised by the officers of the colony.

On reviving Big Rock Creek irrigation district the Llano del Rio colony proceeded to clean out, repair and extend the old district ditches. To avoid litigation the colony also purchased certain water claims adverse to the district that had been sold to the district at the time of organization in 1891. Water is diverted from Big Rock Creek in two places, each heading consisting of a temporary rock dam and wooden headgate. The half-mile tunnel constructed several years after the first failure is still utilized, but does not yield a large supply of water. None of the ditches are yet lined and it is locally estimated that more than one-half of the water diverted is lost in transit. Ultimately, however, it is proposed to line the main ditch with cobble stones and to use vitrified clay pipe, to be made by the colonists, for laterals. It is also proposed to build a reservoir directly above the junction of Rock and Pallett creeks. Run-off data for Rock Creek are meager, so that the water supply available is uncertain. Previous failures having proven the direct flow of this stream to be altogether undependable, the future of this later development will depend first of all on the feasibility and possibility of storage. With an abnormal flow in Big Rock Creek during recent wet years Llano colony has been enabled to accomplish a considerable agricultural development. In July, 1915, the area under cultivation approximated 700 acres, the irrigated crops including alfalfa, pears, apples, peaches, apricots, almonds, grapes, small fruits, corn, truck, and a few sugar beets. The fruit that is expected to receive the principal attention of the colonists is the Bartlett pear. Land in the colony is all held by the colony corporation rather than by individual

PLATE XII.

Fig. 1.—Big Rock Creek at head of Big Rock Creek Irrigation District Ditch, June 30, 1915. (Water above normal.)

Fig. 2.—Head of Big Rock Creek Irrigation District Ditch.

colonists, the colonists merely holding memberships and most of them living in the town of Llano rather than on farms. The colony now has about 400 members living in the district.

BLACK ROCK.

This district was carried January 27, 1915, by a vote of eight for and none against organization. The total area, according to the latest figures furnished by the secretary, is 1,750 acres, of which 1,090 is government land under some form of entry and 660 acres is patented. The land included is in 29 separate parcels ranging from 20 to 200 acres in area and in June, 1915, was held by 27 owners. According to information furnished by the secretary the petition for organization carried the names of or subsequently received the approval of all but six of the landowners, and all who voted at the organization election are said to belong to the families of actual residents of the district. Most of the land that is still unpatented has been filed on within the past two years, several entries having been made in order to be included in the district.

Black Rock irrigation district lies in township 11 south, range 34 east, Mt. Diablo base and meridian, on the west side of Owens River Valley midway between Independence and Big Pine, Inyo County. The lands of the district are generally a plain sloping from the base of the mountains to the floor of the valley, this plain being somewhat broken with ravines and intervening low ridges. The original sources of water planned on were Red Mountain Creek and wells. It was proposed to purchase water rights in Red Mountain Creek from a local mutual water company, which is in turn controlled by a local orchard company. This plan, however, has been abandoned, and the directors are now seeking satisfactory underground sources. The plans for a distributing system submitted by the engineer employed by the district call for 41,773 lineal feet of cement-lined ditches, the estimated cost of which is given as $14,173.00. In reporting on the feasibility of this district in May, 1915, the State Department of Engineering assumes a net duty of water of 1.8 acre-feet per acre per year and estimates that a flow of 10 cubic feet per second, exclusive of transit losses, will be required in order to supply the maximum amount required in any one month. Allowing for transit and application losses of 20 per cent, the amount required during the month of maximum use, when it is assumed, on the basis of local data, that 23 per cent of the total seasonal quantity used will be applied, is given as 12.8 cubic feet per second.

WALNUT.

There has been little if any change in the status of this district from that outlined in the history of the district already given. A substantial concrete intake box has been built at the lower point of waste from the

Standifer or Ranchita users, with a 30-inch concrete pipe under the Santa Fe track connecting the intake box with the concrete-lined ditch above. Inside of the district line 4,600 feet of concrete main pipe lines have been laid ranging in size from 36 inches down to 24 inches, the remainder of the main distributing system being open concrete-lined ditches, with two main branches. Water is still charged for at the rate of ten cents per "head" for twenty-four hours and most of the time sufficient water is available. There has been some misunderstanding with the Standifer or Ranchita users as to the right of the district to receive any day water, the former claiming the entire day supply to the exclusion of the district. A readjustment of this difficulty seems to be pending.

LA MESA, LEMON GROVE, AND SPRING VALLEY.[1]

The question of bringing water to the "back country" of San Diego County has occupied a large share of the attention of the people of that county for nearly two generations. With agricultural conditions admittedly favorable to the successful growth of citrus and other valuable fruits, with climatic and other physical features such as to make the section exceedingly attractive for residence purposes, but with only a meager normal rainfall and a water supply entirely inadequate for irrigating all of the tillable lands of the county, the need for conserving such water as the various local drainage basins afford has long been obvious. The most active movement in that direction occurred in the late eighties and early nineties with the formation of the numerous Wright irrigation districts that were scattered from Escondido to Otay, but which, for reasons already cited, and after being rather violent storm centers for a number of years, finally one after another ceased activity. After the old irrigation districts came private water development and development by mutual water companies, the newer enterprises in several instances taking over rights and works acquired by the districts. Recently the city of San Diego has taken over the properties of one of the larger private interests and still more recently, on October 17, 1913, La Mesa, Lemon Grove, and Spring Valley irrigation district, in part covering territory included in one of the old Wright districts, has been organized to improve the water situation of several of the communities dependent on the San Diego River supply.

La Mesa, Lemon Grove, and Spring Valley irrigation district embraces 14,794 acres around the rural communities from which it takes its name. These communities have been supplied by the Cuyamaca Water Company, which is the successor of the old San Diego Flume Company,

[1] According to last available information activity in this district has been postponed pending negotiations to include it in a municipal water district along with the city of San Diego, to which it is adjacent.

PLATE XIII.

Fig. 1.—Main Ditch of Walnut Irrigation District.

Fig. 2.—Lateral Ditch in Walnut Irrigation District.

local distribution having been attended to by small mutual water companies. Irrigation water rights have generally called for a continuous flow of water at an annual cost of $70.00 per miner's inch, but water has not usually been needed in the winter months, and has frequently not been available when most wanted in the summer. The Cuyamaca system was built in early days when permanent irrigation construction was not common and it has not kept pace with the needs of the communities it has served, which, in addition to La Mesa, Lemon Grove, and Spring Valley, have included El Cajon Valley, La Mesa Heights, and part of East San Diego. In the dry fall of 1911 the necessity for community action in water matters became very evident, and led by the consumers of Spring Valley, an agitation began which finally resulted in the formation of La Mesa, Lemon Grove, and Spring Valley irrigation district. The first steps taken were for the formation of a municipal water district under the municipal water district act of May 1, 1911, and such a district was formed by a vote of 429 to one, September 23, 1912. Some difficulties encountered under that form of organization led to the substitution of the irrigation district and this was organized by a vote of 397 to three.

The area embraced within La Mesa, Lemon Grove, and Spring Valley irrigation district is practically a suburb of the city of San Diego. While some 1,200 to 1,300 acres are already in groves, mostly lemon, and some 7,500 acres have been used from time to time for dry-farmed grain, the section has already become largely used for residence purposes. The town of La Mesa embraces approximately 2,000 acres and while there are a few holdings of several hundred acres within the town limits that have not been subdivided, subdivision plats for most of La Mesa have been recorded and the area will always be essentially a residence one. Outside of La Mesa some 28 recorded subdivisions embrace approximately another 2,000 acres, but as development progresses readjustments of holdings will undoubtedly reduce the number of resident lots. In the lemon section around Lemon Grove 600 or 700 acres are already in groves of mostly five and ten acres, with homes of their owners already established on them. In the same section an additional area of equal extent has been disposed of in holdings of similar sizes and only awaits an additional water supply before being planted and occupied. Much of the area within the district is too rough for cultivation and suitable only for homesites. The entire area within the district that is not susceptible of cultivation has been estimated at about 2,000 acres, but in the absence of a careful soil classification it is not possible to determine how much can be profitably cultivated. To any one at all familiar with southern California communities, however, it is evident that the feasibility of an irrigation district such as that around La Mesa, Lemon Grove, and Spring Valley can not wholly be determined

by the area of land on which groves will be commercially profitable, for when a dependable water supply is obtained the number of strictly home holdings is sure to increase greatly, so that La Mesa, Lemon Grove, and Spring Valley irrigation district more nearly approaches a municipality than is usual among irrigation districts elsewhere.

When La Mesa, Lemon Grove, and Spring Valley irrigation district was organized San Diego River was given as the source of the proposed water supply. After organization an engineer was employed to make a careful study of the feasibility of that source and to outline a complete system of works. The report of the engineer filed in January, 1914, recommended storage on San Diego River just above Mission Valley and but a few miles from the district line. His plan called for an arch dam 103.5 feet high about three-fourths of a mile below the old Mission dam, the water to be impounded amounting to 34,000 acre-feet. Hydrographic data considered in the study of the engineer indicated that during 18 out of 26 years embraced in the available record, water could be taken from the main reservoir at an elevation of 245 feet and delivered through a 24-inch pipe line to the main pump, 4,200 feet down the canyon, at an elevation of 240 feet. From this pumping plant it would be lifted against a total head of 362 feet to the main distributing reservoir, but as about 3,000 acres of the district lie above the main distributing reservoir, a high level service was proposed that should start at an elevation of 700 feet from a high-level reservoir of 2,000,000 gallons capacity. The distributing system leading from the reservoirs as outlined in the plan was to be entirely of riveted-steel pipe, a 12-inch diameter being used on the high-pressure line and from a 36-inch diameter down on the remainder. The plan further provided that when the surface reservoir on San Diego River should become exhausted pumping from wells in the upper portion of the reservoir site should be resorted to. The ultimate supply of water estimated in the report to be furnished was 1,000 inches, but the distributing system planned provided for the handling of only 500 inches for the present. The costs estimated by the engineer were as follows: Dam and reservoir, $733,958.00; wells and pumping plants in upper portion of reservoir site, $133,002.00; main pumping plant, force mains, and summit tunnel, $173,950.00; distributing system, including reservoirs, $246,760.00; total, $1,287,580.00, or at the rate of $87.03 per acre, counting entire area in the district. In estimating the amount of water necessary the engineer counted on one acre-foot per acre per year over 12,000 acres The report stated that while it was realized that a more abundant supply of water would be desirable if available, the situation in San Diego County is governed by the amount which may be depended on rather than the amount which may be an ideal quantity.

On the basis of the engineer's report above outlined an election was held on May 4, 1914, on a proposition to issue the bonds called for in the report. The petition for this election was signed by 799 property owners of the district and the election was carried by a vote of 541 to 10, showing practical unanimity as to the desirability of going ahead. Since that election the district officers have been endeavoring to adjust possible differences over the rights to San Diego River, particularly with the city of San Diego. They have further entered into an agreement with the owners of the Cuyamaca water system to purchase that system in district bonds at par and at a price to be set by the State Railroad Commission, whose decision is expected at any time.[1] The purchase of the Cuyamaca system, if carried through, will necessarily to some extent alter the engineer's plan for storage in and pumping from El Cajon reservoir. The district has been negotiating with the city of San Diego for the joint ownership of the Cuyamaca system, but in the event that such joint ownership is not entered into and the district itself purchases that system according to the agreement with its owners it is expected that the system will be improved and extended as needed to meet immediate demands, the first work probably being the enlargement of the distributing system, the raising of the La Mesa dam, and the construction of an additional reservoir in the mountains.

After La Mesa, Lemon Grove, and Spring Valley irrigation district was organized a valuation of the property by the district officers totaled $4,254,500.00. The values used were taken to be those at which property had changed hands. The valuation assessed for district purposes in 1914 approximated $2,000,000.00, of which $709,000.00 was for city and town lots, the assessors having endeavored to enter the lots at about 40 per cent of their sale value and acreage property at about 50 per cent of its sale value. The maximum acreage valuation outside of the town of La Mesa was $250.00. In La Mesa the base for acreage assessments was $350.00 per acre and the property within the town limits not yet subdivided but subject to subdivision was entered at $400.00 per acre. Outside of La Mesa assessments ranged from $75.00 to $250.00 per acre and lots from $20.00 to $150.00, the latter being for lots 50 feet by 140 feet in the main business section of Lemon Grove. In the city of La Mesa the average assessment for lots was about $250.00 outside of the main business section. In 1914 the assessor found approximately 9,000 separate parcels of land within the district, of which not over 25 were in holdings exceeding 70 acres, these 25 larger holdings embracing a total of approximately 6,500 acres.

Financial operations of La Mesa, Lemon Grove, and Spring Valley district to date have included an assessment of seven mills on a valuation

[1] This decision has since been rendered and a valuation of $745,000.00 placed on the Cuyamaca system. Some difficulty, however, has arisen in connection with the proposed transfer.

of $2,709,000.00 in 1914, yielding a total of $18,963.00, without the allowance for delinquencies, and also a sale of $55,550.00 of the bonds voted in May, 1914, at prices ranging from 85 to par. Of the bonds sold $45,000.00 were paid for land in the El Cajon reservoir site, other bond and assessment expenditures having gone for engineering and general expenses.

SAN YSIDRO.[1]

This is the smallest irrigation district in California, probably the smallest in any of the states, containing only 485 acres. It was formed in 1911 in order to effect a financial reorganization of the water situation in the Little Landers Colony established in Tia Juana Valley, San Diego County, in 1909. The district lies wholly within the old Otay district formed under the organized Wright act and as Otay district has never been dissolved, it was necessary before San Ysidro district could be formed to revive Otay district sufficiently to enable the San Ysidro lands to be excluded. The election on organization of San Ysidro district was held March 11, 1911, and was carried unanimously. After approval by the state irrigation district bond commission, a $25,000.00 five per cent bond issue for reconstructing the irrigation system of the colony was voted December 12, 1912, the entire issue being subsequently sold for cash to a San Diego bank for $25,010.00. The new works built by the district included pipe lines, costing $17,360.17; wells, costing $1,014.37; pump, motor, and pump house, costing $4,915.49; reservoir No. 1, costing $1,319.49, and reservoir No. 2, costing $918.62. Adding $1,480.60 for engineering and superintendence, the total original cost was approximately $27,000.00. Since these works were finished additions have brought the total cost to about $28,000.00.

San Ysidro irrigation district is operated on a combined toll and assessment basis. At first assessments were levied for bond interest only, other expenses being met by monthly water tolls of $1.25 per acre for acreage property and of $1.50 for each 50-foot by 100-foot lot and domestic use thereon. Beginning in 1916, it is planned to collect a greater portion by assessments and to reduce monthly water tolls to about 50 cents per acre for acreage property, 30 cents for each lot, and 60 cents for domestic use in each house. Under this plan more of the financial burden will be borne by nonresident owners than at present. A slight readjustment of the valuations for assessment purposes, by which there will be a more careful differentiation as to character and location of the holdings, is also planned. Up to 1915 all farming lands

[1] In the floods in Tia Juana River in January, 1916, the main pumping plant of San Ysidro irrigation district was washed away and all of the bottom lands partially or wholly destroyed. The district is now obtaining water from a temporary pumping plant.

PLATE XIV.

Fig. 1.—Typical Two-acre Farm in San Ysidro Irrigation District, showing distributing hydrant and pipe.

Fig. 2.—Main Pumping Plant, San Ysidro Irrigation District.

on both mesa and bottoms have been assessed at $100.00 per acre and nearly all lots, whether business or residence, at $75.00 each. The total assessed valuation according to this rating was $69,778.00 in 1914, improvements not being counted. The ruling sale price of the mesa and bottom lands, respectively, is now $750.00 to $800.00 and $500.00, and mesa lands being preferable for residence and the bottom lands for farming.

Little Landers Colony, for which San Ysidro irrigation district furnishes the water supply, was originally laid out in one-acre farms and the occupied holdings are mostly of that area or only a little larger. As an irrigation district San Ysidro district is therefore unique. In its close settlement it has, along with La Mesa, Lemon Grove, and Spring Valley irrigation district, a distinctly municipal character. Water distribution, however, is mainly on an irrigation basis. On the bottom lands 8-inch to 15-inch concrete pipe is used while on the mesa the distributaries are of riveted steel and three inches to twelve inches in diameter. The district builds and maintains a pipe line to each holding. While two distributing reservoirs have been built only the lower one is now needed. Small weirs have been installed on the bottom lands for measuring deliveries to users. Water delivery is in charge of a zanjero and, including his salary and the salary of a powerhouse attendant, and also the monthly power bill, the total monthly cost of managing and operating the district is only a little over $200.00. The district has never defaulted in any payments and has a balance in the bank to care for emergencies. There are now about 140 families resident in the colony.

IMPERIAL.

Imperial district, organized July 14, 1911, by a vote of 1,304 to 360 and containing 523,600 acres, the largest district in the state, is not yet sufficiently advanced in the carrying out of its plans to justify more than a brief comment in this report. The purpose of organizing was to acquire the physical properties of the California Development Company, which now delivers water to Imperial Valley from Colorado River. The character of the present organization of the irrigation system of Imperial Valley is so well understood that it is not necessary to state here more than that the water delivered by the California Development Company is now sold to a number of mutual water companies—seven thus far organized—which in turn deliver it to the irrigators.[1] Under this plan of organization, which was that put into effect by the California Development Company as a part of its general plan for the

[1]A very complete report on irrigation in Imperial Valley, prepared by Mr. C. E. Tait, Irrigation Engineer, Office of Public Roads and Rural Engineering, was printed in 1908 as U. S. Senate Document No. 246, 60th Congress, 1st Session, and can probably be consulted in libraries.

reclamation of Imperial Valley, there has occurred, as is very well known, a very remarkable change within the period of fifteen years—a change from an absolutely arid waste to an irrigated empire approaching 400,000 acres in area, containing a large number of thriving towns and cities, a population estimated at in excess of 30,000, and an equalized assessment of real property, less improvements, as levied for irrigation district purposes, of over $25,000,000.00. The principal condition immediately leading up to the formation of the district was the bankruptcy of the parent California Development Company and the consequent inability of that company to fulfill its obligations to the various mutual water companies and to the settlers. For a number of years it was evident that the irrigation system of the valley must be fully reorganized and its control in some manner passed to the people of the valley. Many of those holding land for which stock in some one of the mutual water companies had not been purchased, and who were anxious to obtain water for that land, and especially the people centering around the county seat of El Centro, were strongly in favor of the district plan. On the other hand, many of the earlier settlers who paid a substantial amount for mutual water company stock, and more particularly those who have been most closely associated with and the principal beneficiaries of the parent company, believed that reorganization on the mutual plan, possibly involving the organization by the various stockholders of the mutual water companies of a holding company to take over the property of the California Development Company, would be preferable. For some time the controversy between the various factions was earnest and bitter, but as indicated by the vote on organization given above, the proponents of the irrigation district plan greatly outnumbered those who preferred a holding company. Even after the organization of the district the opposition sought to contest the confirmation of its organization in court, but later yielded in the face of a preponderance of opinion against them, so that confirmation by the lower court was accomplished and affirmed by the supreme court. Subsequently the levying of the first assessment was contested in the case of *Imperial Land Company* vs. *Imperial Irrigation District,* but the assessment was sustained by the lower court, from which appeal was taken and is still pending.[1] When, after over three years of study and consideration, the directors of the district, after being petitioned by several hundred more landowners than legally required, representing nearly $4,000,000.00 in valuation in excess of the majority stipulated by the law, submitted to the electors of the district for decision on October 29, 1914, a proposition to issue bonds in the sum of $3,500,000.00 for the purpose of acquiring the works of the California Development Com-

[1]This decision has since been rendered in favor of the district.

PLATE XV.

Fig. 1.—Typical Farm Scene in Imperial Irrigation District.

Fig. 2.—Young Cotton Furrowed for Irrigation, Imperial Irrigation District.

pany, a still further effort was made to organize the opposing forces. Even in the town of Imperial, however, which had been the stronghold of the opposition, the majority in favor of the bonds was 132 out of a total vote of 446, while the vote in El Centro precinct was 1,013 in favor of the bonds to 16 against, and in the entire district 3,278 for to 330 against them—a majority of practically ten to one. While many of those who originally opposed the formation of the irrigation district are still of the belief that some other form of organization would have been preferable, further opposition of a substantial character does not now seem likely.

The legal conditions surrounding the acquirement of the works of the California Development Company have thus far prevented the final consummation of the plans of the district to take over those works. The largest interest involved is that of the Southern Pacific Company, which is under agreement with the district to relinquish its claim for the sum of $2,152,500.00 in money or 5 per cent bonds of the district at par. There are, however, other judgment creditors of the California Development Company, notably the New Liverpool Salt Company, which holds a judgment dated January 10, 1908, in the sum of $458,246.23, with interest from that date. According to a report by the chief engineer and general manager of the district made public by the directors in June, 1915, the sum of $5,049,554.78 would have been necessary, on July 1, 1915, to pay out of court all outstanding judgments and interest in full, of which $3,772,128.52 represented the interest of the Southern Pacific Company, including their Mexican holdings. Offsetting against this latter amount the price agreed upon between the district and the Southern Pacific Company, $1,277,426.26 remained as the full amount of the claims on July 1 of all other creditors, making $3,429,926.26 the sum to be paid in out of court settlement, if no reduction were to be made in the claim of the judgment creditors other than the Southern Pacific Company. Final adjustment of the matter is, in September, 1915, still awaiting the outcome of an appeal to the supreme court in the case of *Title Insurance and Trust Company* vs. *California Development Company, Southern Pacific Company, New Liverpool Salt Company et al.*, directing the sale as a whole of the properties of the California Development Company, in order to satisfy the various judgments entered. During the continuance of this and other material litigation there has been much difference of opinion among the people of the district as to the best policy to pursue, some holding out strongly for delaying any settlement until the litigation is finally settled, and others maintaining that, even if waiting will result in the district acquiring the properties of the California Development Company at less than their face or the agreed values, the loss due to existing complications in

control warrants an immediate settlement on the best terms that can be obtained.[1]

In accordance with its agreement with the Southern Pacific Company looking to the purchase of the works of the California Development Company, Imperial irrigation district sought, and obtained, from the California legislature of 1915 validation of the $3,500,000.00 bond issue authorized October 29, 1914.[2] The legislature also authorized the district to acquire works of the California Development Company and its subsidiary companies and successors in California and Mexico by condemnation or purchase, and in case of purchase, to exchange bonds of the district for all or part of the system, provided that the whole bond exchange should not exceed $3,000,000.00.[3] It might be noted here that a constitutional amendment approved by the people November 3, 1914, permits the purchase by irrigation districts, in certain cases, of the stock of any foreign corporation owning the part of any international water system situated in a foreign country—in this case the stock of the Mexican company controlling the portion of the property of the California Development Company lying in Mexico. Prior to voting on the bond issue referred to, the proposed works and the proposed purchase of the system of the California Development Company, and the issuance of the bonds, were approved according to law by the State Engineer. When this bond issue was proposed it was expected, as it still is, that the system of the California Development Company, including all outstanding judgments, could be purchased for something less than $3,000,000.00, but $500,000.00 was included in the issue as an emergency fund to take care of possible needed flood protection along Colorado River.

Assessments have been levied in Imperial district from year to year to cover general expenses, the rate having been two mills on the dollar in 1913 and 1914 and seven mills on the dollar in 1915, the latter being intended to yield $153,324.00. The total equalized district assessment for 1915 is $25,768,837.00. It is interesting to note that although a large part of the land in Imperial district is still unpatented, owners of unpatented lands, in spite of the fact that no lien can be attached to such lands through an irrigation district assessment, pay their assessments as readily as those who have patented land. It is fully recognized that land in Imperial Valley is worthless without water, and as the supply when properly distributed is admitted to be ample, there is

[1] The Imperial system was finally taken over by Imperial irrigation district in the summer of 1916.

[2] Statutes 1915, chapter 17.

[3] Statutes 1915, chapter 172. A general statute was also passed (Statutes 1915, chapter 507) providing that bonds of irrigation districts authorized by a vote of four-fifths of the electors shall be held valid, and as the $3,500,000.00 bond issue of Imperial district was carried by more than four-fifths of the electors voting, this act is a further validation of the Imperial bonds. Imperial district bonds were also validated by the superior court of Imperial County, April 6, 1915.

no hesitancy in the payment of assessments on account of the lack of patent. In making up the district assessment roll the assessor of the district appraises all good farm lands in the district at the rate of $50.00 per acre. Land which it is impracticable to irrigate, or which is too heavily impregnated with alkali to be valuable, is assessed at from $5.00 to $25.00 per acre, and river bottom lands at about $5.00 per acre. Town lots are assessed at county valuations, acreage within the incorporated town limits at $100.00 per acre, and land in unincorporated areas, but in tracts and subdivisions and having maps recorded, at $75.00 per acre.

Lying in Imperial Valley but outside of Imperial irrigation district are large areas of land which would be productive if waters could be supplied. There is some difference of opinion as to the total area in the valley that can ultimately be watered, but there is a general agreement that a considerably larger area than that included in the district will ultimately be brought under irrigation. A petition which, it is said, is likely to receive favorable consideration by the directors, and which requests the inclusion in the district of about 100,000 acres embraced in a narrow strip east and north of the district extending from the Mexican boundary to the shoreline of Salton Sea, has already been presented to the directors. Part of the land included is now submerged by Salton Sea, but with the recession of its waters this land will become agricultural and the owners of it have signified their willingness to pay a nominal district assessment on it while still under water.[1]

When the plans of Imperial irrigation district to take over the system of the California Development Company are finally consummated, as they undoubtedly must and will be, an interesting question will arise as to the continuance of the present mutual water companies which are distributing the water supplied by the California Development Company. The shareholders of the mutual water companies have in general seemed to hold out for a continuance of distribution through the medium of these companies, which are admittedly very efficiently managed. Water is paid for by the irrigators at fifty cents per acre-foot, which is the price paid by the mutual companies to the California Development Company, the stockholders of the mutual companies, however, paying annual assessments for maintenance and operation in addition to the water charge. A general basis for the settlement of this question has not yet been reached.

Imperial district has gone on record as approving the idea that the affairs of large irrigation districts should be mainly in the hands of a general manager, and they called to that position the man who originally worked out and later carried into effect the organization of the parent

[1]Since the above was printed the area of Imperial district has been increased from 523,600 acres to 576,600 acres.

promoting company. When originally appointed his salary was fixed at $750.00 per month—the largest salary paid by any irrigation district—but pending the final purchase of the water system by the district the salary of the manager, as well as the salaries of other officers, including the board of directors, have been reduced to a minimum.

COURT DECISIONS AFFECTING CALIFORNIA IRRIGATION DISTRICTS.

The extent of litigation involving California irrigation districts was brought out in the history of activities under the original Wright act. A study of the reported cases in the California supreme and federal courts discloses ninety-one decisions that have construed the original act or the act of 1897 and amendments and supplementary statutes.[1] Many points have been taken up in the decisions. For the first few years attacks on the law were mainly directed against its constitutionality, although in most of the early litigation involving constitutionality many other points were considered. Also, many of the cases hinged on the validity of assessments and on tax sales. The more recent cases have largely involved the collection of interest and principal of bonds of the old districts that were abandoned. The various decisions that have been rendered and the resulting clarification of the district law are quite fully discussed by the standard law writers on irrigation and water rights,[2] but for the benefit of those to whom the standard law books are not available, and in order to present some of the facts of the decisions in brief form, the decisions on a few of the main principles involved, particularly those of especial interest to those contemplating the organization of irrigation districts, are briefly epitomized below.

CONSTITUTIONALITY.

A total of 20 cases have been found involving the constitutionality of the California irrigation district law, of which at least four in the California supreme court and two in the federal courts considered the broad principles of the law. It will be remembered that the Wright act was passed in 1887 and it might be recalled that 30 districts were formed up to and including 1891 and 19 more up to and including 1895. Almost as soon as the early districts were organized opposing owners of large ranches and of town lots within the towns included in the districts sought to defeat the districts by attacking the constitutionality of

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[1] A complete list of irrigation district cases in the California supreme court and in the federal courts with subjects dealt with is given in the addenda.

[2] For a general review of decisions reference is made to Wiel, Samuel C., Water Rights in the Western States, 3d ed., 1911, and Kinney, Clesson S., A Treatise on the Law of Irrigation and Water Rights, 2d ed., 1912.

the law, but by December, 1891, four leading decisions had been handed down by the California supreme court upholding it. In *Turlock Irrigation District* vs. *Williams*,[1] decided May 31, 1888, the act was held constitutional on the ground that a district organized under it was at least a *quasi* public corporation and as such was entitled to levy assessments and condemn property in the manner and for the uses described in the statute. The same view as to the *quasi* public nature of irrigation districts was taken in *Central Irrigation District* vs. *De Lappe*,[2] in which it was also held that the proceedings for organization should be liberally construed. In *Crall* vs. *Poso Irrigation District*[3] it was further stated that the legislature had power to pass such an act and this same ground was taken in *In re Madera Irrigation District*,[4] decided December 14, 1891, which also held among other things that all lands within a district need not be directly benefited by irrigation to constitute a public use. In these decisions the question of the taking of private property for private use and without due process of law were quite conclusively settled, so far as the state courts were concerned, in favor of the law. In the first federal case involving constitutionality, however, that of *Bradley* vs. *Fallbrook Irrigation District*,[5] it was held that the taking of private property to furnish water to land owners alone is not sufficiently a public use, and that the Wright act was invalid as authorizing the taking of private property without due process of law. This adverse decision practically halted for a time all activity under the law, but in the quite celebrated case of *Fallbrook Irrigation District* vs. *Bradley*,[6] decided November 16, 1896, the adverse decision of the lower federal court was reversed and it was held that the provision of the Wright act for confirming or contesting an irrigation district tax brings the proceeding within "due process of law"; that the irrigation of arid lands is a public purpose; and that the irrigation district legislation furnishes ample due process of law and is constitutional. The constitutionality of the Wright act in so far as its general principles are involved has not been questioned since this decision, but both before and after it the constitutionality of certain features of the district law has been questioned and carried to the state and federal courts.[7] So far as

[1] 76 Cal. 360.
[2] 79 Cal. 351.
[3] 87 Cal. 140.
[4] 92 Cal. 296.
[5] 68 Fed. 948.
[6] 164 U. S. 112.
[7] In addition to cases cited, see *In re Central Irrigation District*, 117 Cal. 382; *Lahman* vs. *Hatch*, 124 Cal. 1; *People* vs. *Linda Vista Irrigation District*, 128 Cal. 477; *Escondido High School District* vs. *Escondido Seminary*, 130 Cal. 128; *Nevada National Bank* vs. *Board of Supervisors of Kern County*, 91 Pac. 122; *Fogg* vs. *Perris Irrigation District*, 154 Cal. 209; *In re South San Joaquin Irrigation District*, 161 Cal. 345; *Imperial Water Company No. 1* vs. *Board of Supervisors of Imperial County*, 162 Cal. 14; *Tregea* vs. *Modesto Irrigation District*, 164 U. S. 179; *Herring* vs. *Modesto Irrigation District*, 95 Fed. 705, and *People ex rel. Brady* vs. *Browns Valley Irrigation District*, 119 Fed. 535.

adversely affecting constitutionality is concerned the net results of the additional litigation have been decisions that a technical portion of section 4 of the confirmation act of 1889,[1] a portion of section 17 of the Wright act as amended in 1893 (authorizing boards of directors, as additional security for the payment of bonds, to pledge by mortgage, trust deed, or otherwise, all property of the district),[2] and section 4 of the act of 1897 (providing for appeal from the board of supervisors directly to the superior court),[3] all of which sections have since been amended to meet objections raised to them, were unconstitutional.

ORGANIZATION.

The first case in the California supreme court in which the details of the organization of irrigation districts were considered was *Central Irrigation District* vs. *De Lappe*,[4] decided May 31, 1889. It was held in this case that the primary purpose of the organization of an irrigation district is to perform certain important public functions, and that a reasonably liberal rule of construction should be adopted by the courts to carry out the purposes of the law. In *Fallbrook Irrigation District* vs. *Abila*[5] it was held that the term "freeholders owning lands" must be strictly construed to mean owners of land in the general and unqualified sense of the term, so that they may fully appreciate the responsibilities they are about to incur. In *Cullen* vs. *Glendora Water Company*[6] it was held that an agreement between the organizers of an irrigation district and a water company for taking over the system does not render the organization of the district fraudulent if it is not shown that the organizers do not intend to carry out the agreement. In the same case it was held that the inclusion of unpatented railroad land does not make the organization of a district invalid. In *In re Central Irrigation District*[7] it was held that the holders of small residence lots in towns and cities are not such owners of land within the meaning of the Wright act as to make them qualified signers of the original petition for the organization of the district. Instead, it was held that such qualified signers must be *bona fide* owners of agricultural land desiring to improve it by conducting water upon it. In *Fogg* vs. *Perris Irrigation District*[8] it was stated that the fact that a majority of those signing a petition as freeholders were such only temporarily and nominally, on the agreement that land conveyed to them should be reconveyed after the organization, was a fraud. In *Imperial Water Company No. 1* vs. *Board of Super-*

[1] *Cullen et al. vs. The Glendora Water Company*, 113 Cal. 503.
[2] *Merchants' National Bank of San Diego vs. Escondido Irrigation District*, 144 Cal. 329.
[3] *Chinn et al. vs. Superior Court of San Joaquin County*, 156 Cal. 478.
[4] 79 Cal. 351.
[5] 106 Cal. 355, 365.
[6] 113 Cal. 503.
[7] 117 Cal. 382.
[8] 154 Cal. 209.

visors of Imperial County,[1] decided January 8, 1912, it was held that where town lots are not irrigable and their owners are not eligible as petitioners, they must be rejected; also, that the board of supervisors has power to include within the boundaries of an irrigation district land not within the boundaries set out in the petition. In *Herring* vs. *Modesto Irrigation District*[2] it was held, following closely the decision of the United States supreme court in *Fallbrook Irrigation District* vs. *Bradley*,[3] that the question of benefits to be derived from irrigation in a proposed district is to be decided by the county supervisors and that in the absence of fraud or bad faith on their part their decision is conclusive.[4]

ASSESSMENTS.

There have been so many decisions affecting assessments and so many of these have dealt with technical legal matters that no effort will be made to summarize them fully. In general, it may be said that in numerous early cases the broad principle was laid down that the method of making and collecting assessments for irrigation districts need not follow exactly the mode provided for in the constitution for taxation for general state purposes, the distinction being recognized between general taxation and its restrictions and assessments for local improvements;[5] that although an apportionment of expenses for local improvements is to be made according to the benefits received by the property assessed, yet the power to make such apportionment rests on the general power of taxation, and the apportionment itself does not depend upon the fact of local benefit in any other sense than that all taxes are supposed to be based upon the benefit received by the taxpayer;[6] that it is within the power of the legislature to subject state lands to any just liability of the character in question, but the legislature has no such power over the public lands of the United States;[7] and that the board of directors may exercise discretion as to the amount of assessment to be collected, for while its action is subject to the control of the judiciary, and the collection of an assessment may be enjoined in case the board should seek to raise an excessive amount,[8] the courts have no authority to determine the amount to be raised or what proportion of the assessments shall be collected.

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[1] 162 Cal. 14.
[2] 95 Fed. 705.
[3] 164 U. S. 112.
[4] The decisions on organization have covered many other points than those cited and there have also been additional cases as follows: *In re Bonds of Madera Irrigation District*, 92 Cal. 296; *People* vs. *Perris Irrigation District*, 142 Cal. 601; *Miller* vs. *Perris Irrigation District et al.*, 85 Fed. 693; 92 Fed. 263; *Perris Irrigation District* vs. *Thompson*, 116 Fed. 852; *Tulare Irrigation District* vs. *Shepard*, 185 U. S. 1.
[5] *Turlock Irrigation District* vs. *Williams*, 76 Cal. 360.
[6] *In re Bonds of Madera Irrigation District*, 92 Cal. 296.
[7] *City of San Diego* vs. *Linda Vista Irrigation District et al.*, 108 Cal. 189.
[8] *Boskowitz et al.* vs. *Thompson et al.*, 144 Cal. 724.

BONDS.

As in the case of assessments, the decisions on irrigation district bonds have been so many and in some cases so technical that a full review of them here is not consistent with the purposes of this report. Therefore, only a few of the main questions brought out in the decisions will be referred to. In general, it may be stated that the decisions have covered nearly every phase of the issuance, sale, and redemption of irrigation district bonds, and have necessarily had to do with the validity of district organizations.

In *Cullen* vs. *Glendora Water Company*,[1] decided July 25, 1896, it was held that the language of the Wright act clearly implied that there must be some plan or plans in the alternative before an estimate of costs can be made prior to a bond issue, and that without such plan or plans, no real estimates can be made.[2] In *Hughson* vs. *Crane*[3] it was adjudged that the directors of a district have no authority to appropriate the bonds which the electors have voted to issue for the construction of works to the payment of salaries or to expenditures incurred in the management of the property; also that bonds issued to a contractor in payment for the construction of a dam are issued in violation of the statute and can not, in his hands, be valid obligations against the district. In *Stimson* vs. *Alessandro Irrigation District*,[4] decided January 23, 1902, it was held that the board of directors has power to acquire water works by construction, purchase, or condemnation, and to issue bonds of the district in payment therefor, and that the board has no other powers except those expressly given or implied as necessary to carry out the main purposes of the act. In *Baxter* vs. *Vineland Irrigation District*,[5] decided April 3, 1902, it was held that no question of irregularity such as in keeping the records, conducting the elections, failing to advertise the bonds for sale, etc., can be considered when the bonds are in the hands of *bona fide* purchasers or holders for value, without notice of the alleged irregularities. In *Leeman* vs. *Perris Irrigation District*,[6] decided October 9, 1903, it was held that the board of directors has authority to dispose of bonds by only two modes, all others being excluded by plain implication, and that it can not reasonably be said that the power to exchange bonds for warrants issued for construction work is necessarily implied from the express power to exchange bonds in payment for property; also that one who purchases bonds knowing that they were negotiated in a manner not authorized

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[1] 113 Cal. 503.
[2] Recent amendments to the act of 1897 which now require a report by the State Engineer as a condition precedent to the calling of bond election are fully referred to in the review of legislation, pp. 48 and 49.
[3] 115 Cal. 404.
[4] 135 Cal. 389.
[5] 136 Cal. 185.
[6] 140 Cal. 540.

by law is not a *bona fide* holder. In *Nevada National Bank* vs. *The Board of Supervisors of Kern County*[1] the California court of appeals for the third district decided that it was well established that the proper course to pursue when municipalities refuse to pay their bonds is by an action at law to establish the validity of the bonds and the amount due thereon, and then to apply for a writ of mandate to compel the proper authorities to raise what is required to satisfy the debt by assessment and levy provided by statute.[2] In *Stowell* vs. *Rialto Irrigation District*,[3] decided February 17, 1909, it was adjudged that a contract to deliver bonds for water rights and pipe lines is within the law and that bonds issued from time to time for completed portions of an irrigation system are valid; for by the use of the words (in section 15 of the act of 1897) "works constructed and being constructed" the legislature clearly evidenced its intention to authorize districts to negotiate for water systems in advance of their total completion. In *Harelson* vs. *South San Joaquin Irrigation District*,[4] decided by the state court of appeals of the third district on November 8, 1912, it was held that no time is prescribed within which a petition to have land excluded from a district may be filed, and that although a bond issue may have been authorized, no lien and consequent estoppel of the landowner can arise until the bonds have been sold.

In addition to decisions in the state supreme and appellate courts many decisions affecting irrigation district bonds in California have been rendered in the federal courts. In *Miller* vs. *Perris Irrigation District*,[5] decided February 20, 1899, the circuit court for the southern district of California held that bonds issued for "labor and material" are invalid. In *Herring* vs. *Modesto Irrigation District*,[6] decided June 30, 1899, the circuit court for the northern district of California held that the exclusion of lands from a district after organization does not affect an order for a bond issue, provided no bonds have then been sold. In *Thompson* vs. *Perris Irrigation District*[7] the circuit court for the southern district of California held June 11, 1902, that *mandamus* is the proper remedy in the United States circuit court for collecting a judgment obtained therein against a California irrigation district; also that if the directors fail to make a levy for payment of the bonded obligations, it is the duty of the county supervisors so to do and *mandamus* will lie against them therefor.[8]

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[1] 91 Pac. 122.
[2] In this connection it is well to refer to section 39 of the act of 1897 as amended, which makes it under certain circumstances the duty of the district attorney or the attorney general to take appropriate action for enforcing the levying and collection of assessments.
[3] 155 Cal. 215.
[4] 128 Pac. 1010.
[5] 92 Fed. 268.
[6] 95 Fed. 705.
[7] 116 Fed. 769.
[8] In this connection reference is again made to section 39 of the act of 1897.

CONDEMNATION.

This subject was first under consideration by the California supreme court in *Turlock Irrigation District* vs. *Williams*,[1] decided May 31, 1888, which held that the provisions in the Wright act relative to the condemnation of private property were legal and constitutional. In *Rialto Irrigating District* vs. *Brandon*[2] it was held that a right of way may be condemned for a pipe line, as well as for "ditches and canals," for the term "system of works" is broad enough to included pipe lines, flumes, or other conduits for water.

USE OF WATER OUTSIDE OF DISTRICTS.

In *Hewitt* vs. *San Jacinto and Pleasant Valley Irrigation District et al.*,[3] *decided* April 3, 1899, it was held that an irrigation district has power to deliver water on lands outside its own territorial confines if it has purchased the property of a water company subject to this burden, and on no just principle can it hold the property discharged therefrom. A municipal corporation may, for proper corporate purposes, both hold property and perform contracts beyond the municipal boundaries. In *Jenison* vs. *Redfield*,[4] decided July 30, 1906, it was held that the ultimate purpose of an irrigation district is the improvement, by irrigation, of the lands within the district, and this precludes the district from allowing water to be taken outside of the district for the irrigation of other lands, even by a landowner within the district who wishes to use his proportionate share of district water on his own lands outside.

INCLUSION OF UNPATENTED GOVERNMENT LANDS.

In *San Diego* vs. *Linda Vista Irrigation District*,[5] it was held that the legislature has no such power over the public lands of the United States as to subject them to liability for assessments in an irrigation district. In *Nevada National Bank* vs. *Poso Irrigation District*[6] it was held that so long as land remains public land of the United States no liability created by the state or an irrigation district can attach thereto. The sale and conveyance by the United States of land within an irrigation district does not operate to charge it with a pre-existing liability not created or assented to by the government or its grantee, and such land is not a part of an irrigation district, is not subject to any lien for district bonds, and is not subject to any assessment for the payment of any debt or liability of the district.

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[1] 76 Cal. 360.
[2] 103 Cal. 384.
[3] 124 Cal. 186.
[4] 149 Cal. 500.
[5] 108 Cal. 189.
[6] 140 Cal. 344.

In *Cullen* vs. *Glendora Water Company*[1] it was held that the inclusion of unpatented railroad land does not make the organization of the district invalid.

INCLUSION OF MUNICIPALITIES.

In *Modesto Irrigation District* vs. *Tregea*,[2] it was held that municipalities may properly be included within the boundaries of irrigation districts, for they are indirectly and to a certain extent directly benefited by irrigation, as to the merits of which the judgment of the board is conclusive. Furthermore, every taxpayer receives an allotment of the water proportional to his taxes and this he may use or sell, thus receiving a full equivalent for the tax assessed to him. Again, in *In re Madera Irrigation District*[3] it was held that the inclusion of a town neither renders the act unconstitutional nor invalidates the organization of the district.

INCLUSION AND EXCLUSION OF LANDS.

In *Cullen* vs. *Glendora Water Company*[4] it was held that the board of supervisors has discretionary power as to the inclusion or exclusion of lands and that the only objection that can be raised is as to the abuse of such power, or fraud. In *Imperial Water Company No. 1* vs. *Board of Supervisors of Imperial County*,[5] decided January 8, 1912, it was held that the board of supervisors has power to include within the boundaries of a district land not within the boundaries set out in the petition. In *Central Irrigation District* vs. *De Lappe*[6] it was held that the judgment of the board is final as to the exclusion of lands on the basis of their nonirrigability from the proposed common system of works. In *Modesto Irrigation District* vs. *Tregea*[7] it was held that lands may be excluded from a district after the authorization of a bond issue, provided no bonds have been issued or the holders of outstanding bonds consent. In *Harelson* vs. *South San Joaquin Irrigation District*,[8] decided November 8, 1912, the state court of appeals for the third district of California held that the term "another source," as used in section 78 of the act of 1897 (in connection with lands entitled to be excluded from an irrigation district) does not necessarily mean another source of works but may mean any source by which the lands are in fact being irrigated, as for instance, a pumping plant; but in order to counteract this decision section 78 was amended in 1911 by adding a proviso

[1] 113 Cal. 503.
[2] 88 Cal. 334.
[3] 92 Cal. 296.
[4] 113 Cal. 503.
[5] 162 Cal. 14.
[6] 79 Cal. 351.
[7] 88 Cal. 334.
[8] 128 Pac. 1010.

at the end that lands irrigated by underground pumped waters and benefited by subirrigation from the irrigation or drainage works of a district can not claim exclusion, although they are not assessable except for principal and interest on bonds if thus irrigated on organization and still exclusively so irrigated each year. In *Herring* vs. *Modesto Irrigation District*[1] the United States circuit court for the northern district of California held that the exclusion of lands from a district after organization does not affect an order for a bond issue, provided no bonds have then been sold.[2]

EFFECT OF ACT OF 1897 ON DISTRICTS PREVIOUSLY ORGANIZED.

This question has been adjudicated by the federal courts only. In *Herring* vs. *Modesto Irrigation District*,[3] decided June 30, 1899, it was held by the circuit court for the northern district of California that no contract, obligation, lien, or charge incurred by an irrigation district prior to 1897 was affected, impaired, or discharged by any of the provisions of the act of 1897, but such liabilities were expressly continued in section 109 thereof. In *Board of Supervisors of Riverside County* vs. *Thompson*,[4] decided May 11, 1903, it was held by the circuit court of appeals for the ninth circuit on error to the circuit court for the southern district of California that the act of 1897 applies to all existing irrigation districts, no matter when organized, for it recognizes the existence and validity of districts theretofore organized and makes them subject to the provisions of the act so far as applicable.

SUMMARY AND CONCLUSIONS.

1. The original Wright irrigation district act and the amended act of 1897 have together been on the statute books of California for twenty-eight years and during this time, and in spite of many early mistakes and failures, some of which resulted in entire or partial repudiation of bonded indebtedness, the district form of irrigation organization has become an established California institution as to the effectiveness and success of which there can no longer be any question. No irrigation district organized under the amended act of 1897, or since reorganization under that act, has defaulted in the payment when due of either principal or interest of any bonded indebtedness.

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[1] 95 Fed. 705.
[2] For an additional case on inclusion of lands, see *Central Irrigation District* vs. *De Lappe et al.*, 79 Cal. 351.
[3] 95 Fed. 705.
[4] 122 Fed. 860.

2. Failures under the original act of 1887 may, in the main, be attributed to one or more of the following conditions or causes:

(*a*) Lack of any provision for state control or supervision through which the organization of unwise and infeasible districts could be prevented by the state government.

(*b*) The granting of too large a measure of power to minority landowners in the matter of initiating district projects, resulting in the formation of a number of districts in which the majority of the established substantial interests was opposed to such organization; also, resulting in some cases in the formation of districts by a relatively few occupants of desert holdings who in no way represented the interests of those who ultimately would have had to pay for the district improvements had the project been successful.

(*c*) Absence of some proper limitation on the power of districts to create debt without the assent of those representing at least a majority of the property to be charged with the debt. This lack resulted in many cases in the voting and issuance of bonds far in excess of amounts conditions at the time justified, inevitably arousing bitter opposition on the part of the large landowners.

(*d*) In the case of a considerable number of the districts organized, a too strongly speculative attitude on the part both of the promoters and organizers of such districts and of those who purchased the bonds that were issued.

(*e*) Lack of data as to water supply and construction costs, resulting in engineering mistakes that even a small measure of public control should now be able to prevent.

(*f*) In a few cases, willingness of engineers of repute to report favorably on district projects for which there was no physical justification and for which, in some cases, there was no moral justification.

(*g*) Misconception by many of the purposes of the district law and of the extent of the power over riparian rights granted by it to nonriparian owners.

(*h*) Excessive optimism of the period of greatest activity under the law, followed by the industrial panic of 1893, during which feasible projects in some cases met the same fate as those that were not feasible.

(*i*) General attack on the principles of the law under financial support of a number of both large and small landowners who were convinced by shrewd attorneys that the Wright act could be proven unconstitutional and debts incurred under it thereby be invalidated.

(*j*) In some cases, failure of the organizers of districts to give due regard to economic feasibility at the time the projects were undertaken.

3. Forty-nine irrigation districts were organized under the original Wright act. Of these, twenty-four disorganized or were abandoned prior to any substantial activity and without the issuance of any bonds.

One (Walnut) never issued any bonds but has been continuously successful from the start.

4. Of the twenty-four of the old districts that issued bonds, nine were essentially speculative, five were *bona fide* but clearly unwise, one large one was *bona fide* and entirely feasible physically but was unsupported by a sufficient public opinion to justify it at the time organized, four simply failed of success, and seven, including two classed as speculative when organized, are now operating. Sixteen of the twenty-four have effected a financial settlement and bond suits are pending in three others.

5. Of the eight districts organized under the original Wright act that are operating in 1915, Modesto, Turlock, and Alta have most completely made use of the financial and administrative provisions of the district law and are unquestionably successful. Browns Valley and Tulare districts have entirely eliminated their bonded indebtedness, according to the terms of settlement agreed on with their bondholders, and are now operated on a tolls basis with conditions having reached stability in Tulare district. Little Rock Creek district has recently refunded its original bonded indebtedness on a compromise basis and has rehabilitated and greatly improved its water system out of the proceeds of an additional small bond issue. Big Rock Creek district has recently been restarted under the auspices of a socialist colony and settlement suits covering the old bonds are pending. Walnut district continues to run successfully as an agency for the ownership and operation, on a tolls basis, of the small area included.

6. Nine irrigation districts have been organized under the act of 1897 and its amendments.[1] Of these, South San Joaquin, Oakdale, and San Ysidro have mainly completed construction. Imperial has voted the necessary bonds and will take over the system of the California Development Company as soon as certain preliminary uncertainties are cleared up;[2] Anderson-Cottonwood and La Mesa, Lemon Grove, and Spring Valley[3] have laid out or have agreed to purchase works and have voted bonds therefor, and Waterford,[4] Alpaugh,[5] and Black Rock have not yet determined upon procedure for acquiring a water supply and distributing works.

7. The original Wright act of 1887, as re-enacted in 1897 and amended from time to time since then, has proven to be a workable and generally satisfactory measure, the amended law having corrected the chief defects and supplied some of the essential omissions of the earlier law, as well as having added several entirely new features designed to

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[1] This has since been increased to fourteen. See footnote on page 60.
[2] See footnote on page 102.
[3] See footnote on page 94.
[4] See footnote on page 74.
[5] See footnote on page 90.

give the state government a larger responsibility in aiding and watching irrigation districts under the broad theory that irrigation districts are in some measure agencies of the state in furthering irrigation development. It seems quite evident, however, that further improvement is possible, in part as suggested below.

8. The present provision of the California irrigation district act requiring a report by the State Engineer on proposed districts prior to their organization might well be amended to require a careful investigation and physical examination by the State Engineer prior to report, instead of merely requiring a somewhat negative report, as at present; and to make this possible it would seem that the State Engineer should be allowed such reasonable time as he might require, instead of the present thirty days, in which to make his examination and report.

9. Operation of the existing law providing for a report by the irrigation district bond commission on district bond issues has materially strengthened the financial status of approved California irrigation districts and resulted in a definite improvement in irrigation district construction. It is believed, however, that the absence of any control by the state over the expenditure of the proceeds of bond sales where the issuance of the bonds has been approved by the bond commission is unfair both to the state and the investing public, and that consequently the present law should be amended to require approval by the State Engineer of all work done with the proceeds of approved bond issues.

10. The measure of control and supervision that should be exercised by the state over irrigation districts is admittedly subject to argument. In the opinion of the writer, however, the weight of argument, in the case of California, is on the side of strengthening and enlarging the measure of control and supervision now exercised, both as suggested in paragraphs 8 and 9 above, and to give the State Engineer at least advisory jurisdiction over the financial operations of irrigation districts, to the end that efficiency in irrigation districts shall be increased, and the security of bondholders strengthened. In this latter connection it is suggested that the state might well provide an as nearly as possible uniform system of irrigation district accounting, for use especially during construction, but also in connection with operation and maintenance.

11. An annual conference of irrigation district officials to be called by the State Engineer, would, it is believed, work for a more uniform and a better administration of organized irrigation districts, and might lessen the now too frequent amendment of the district law to meet special conditions in particular districts. The connection of the State Engineer with such a conference might inject into its deliberations the viewpoint of the public, which viewpoint has been almost wholly lacking in legislation framed and submitted to the legislature by the districts themselves. Such a conference might, for instance, among numerous

other matters, well consider the wide variation in the levying of irrigation district assessments, to which attention is called in the discussions of the present status of existing districts.

12. The growing tendency in some districts toward employing a competent irrigation district manager who shall, subject to the board of directors, have full control of the district business, seems to be in line with a better business administration, and for that reason is to be strongly commended. There is a feeling in some of the districts that the present per diem system of compensating members of boards of directors for time devoted to district business is responsible for some of the directors giving much time to matters that might more properly be dealt with by a general manager; also that in addition to increasing the cost of administration, by their doing so, the willingness of individual directors to deal with such matters is quite apt to weaken the authority of the engineer or superintendent and thus make his task the more difficult. A remedy for this condition might be found in a board of three, instead of five directors, the members to receive regular annual salaries commensurate with the time devoted by them to district business.

13. The recent great interest in California in the irrigation district form of organization justifies such careful watchfulness by the state as will prevent unduly rapid irrigation district expansion, in advance of real economic justification.

14. The main problem before several of the districts recently organized is to obtain settlers for the lands for which water has been made available, and one of the most prevalent deterrents to rapid settlement would seem to be the high prices asked for land. Unfortunately, no wholly satisfactory method has yet been devised for preventing undue speculation in land in irrigation districts, along with that on projects of other forms, based on the making of irrigation water available. If the experience of the last decade is to profit recently-formed irrigation districts in California, it is believed that the prevention of land speculation, as well as the other problems of modern land settlement, must be given careful consideration by them as districts, instead of leaving such matters wholly to individuals, as in the past. There is no apparent reason why irrigation districts should not and could not enter into agreements with the owners of lands within such districts that are open for colonization providing for the sale of such lands to settlers at an agreed price, and under such conditions and terms of payment as might be mutually determined to be satisfactory to the seller and within the means of the purchaser. An amendment to the district law permitting irrigation districts to enter into such agreements might open to irrigation districts a new way of helping themselves to attain a more rapid development and success.

ADDENDA

I.

STATISTICAL LIST OF IRRIGATION DISTRICTS

Districts organized	County or counties in which located	Year organized	Area, acres (in most cases, approximate)	Bonded indebtedness incurred
Happy Valley	Shasta	1891		None
Orland	Glenn (formerly Colusa)	1887		None
Kraft	Tehama and Glenn (formerly Tehama and Colusa)	1888	13,000	None
Orland Southside.	Glenn (formerly Colusa)	1888	25,000	None
Central	Colusa	1887	156,550	About $570,000
Colusa	Colusa	1888	105,000	None
Browns Valley	Yuba	1888	44,328	$140,000
Modesto	Stanislaus	1887	81,143 (now 81,183)	Original $1,150,000; funding, $1,341,511; and $256,000 additional to Jan. 1, 1915. Later, $610,000. Total now outstanding $1,605,511.

ORGANIZED UNDER THE WRIGHT ACT OF 1887.

Extent of operations	Basis of financial settlement
Accomplished nothing and soon abandoned. Replaced by small cooperative company.	On order of superior court in 1902 supervisors levied assessment sufficient to meet judgment covering all debts left.
Accomplished nothing and soon abandoned.	Left no indebtedness.
Organization and bond issue of $80,000 confirmed, but soon abandoned owing to general discouragement and internal dissensions. Later most of land petitioned out of district.	All indebtedness paid by voluntary assessment.
Made surveys and voted $200,000 bonds, which declared void prior to issue. Abandoned when opposition gained control.	All indebtedness paid by voluntary assessment.
Operated several years, built about 40 miles of canal, ceased work about 1892 due to inability to sell bonds, and finally declared illegally organized by supreme court in 1897. Works leased in 1903, lease now being held by Sacramento Valley Irrigation Company and its successors. Landowners in old district recently held by supreme court to have preferential right to water in Central canal.	Bonds mostly bought by Sacramento Valley Irrigation Company at reported price of 35 cents on dollar and held as protection for lands purchased in district by it. Suits involving validity of bonds never prosecuted to conclusion. Company made compromise with some landowners.
Accomplished nothing and disorganized in 1893 by vote of 208 to 18.	Left no indebtedness.
Built headworks in North Yuba River, 9 miles of flume, 25 miles of main canal, and some laterals, which made water available to about 4,500 acres. Inactive for a number of years due to litigation, but finally declared legal by United States court in 1905. Now operated under contract with power company and by water tolls.	Bonds and interest coupons compromised in 1906 at 30 cents on dollar.
By July 1, 1895, built dam, headworks, 9,000 feet flume and earthworks down to district line. Inactive next 7 years. Rehabilitated 1902, works extended, and now active and successful, 52,381 acres being irrigated in 1914.	Original indebtedness funded in 1902 dollar for dollar less refund of 5 years' interest on funding bonds. All obligations since funding paid in full as due.

STATISTICAL LIST OF IRRIGATION DISTRICTS ORGAN

Districts organized	County or counties in which located	Year organized	Area, acres (in most cases, approximate)	Bonded indebtedness incurred
Turlock	Stanislaus and Merced	1887	176,210 (now 175,566)	Original $1,170,000; funding, $1,156,000; additional to Jan. 1, 1915, $1,416,800; total now outstanding $2,572,800.
Madera	Madera (formerly Fresno)	1888	280,000	None
Sunset	Fresno and Kings	1891	318,500	At least $329,500
Huron	Fresno	1892	25,000	None
Selma	Fresno	1890	200,000	None
Alta	Tulare, Fresno, and Kings.	1888	130,000	Original, $543,000; funding about $480,000.
Tulare	Tulare	1889	39,360	$500,000
Tipton	Tulare	1891	17,000	$50,000

IZED UNDER THE WRIGHT ACT OF 1887—Continued.

Extent of operations	Basis of financial settlement
Construction periodically under way to 1901 and system largely completed. After long litigation bonds finally held valid in 1901 and reorganization and rehabilitation of system rapidly followed. Now active and successful.	Original indebtedness funded in 1902 on basis of 80.5 cents on the dollar. All obligations since funding paid in full as due.
Surveys made and $850,000 bond issue voted. Sought to purchase Madera canal system but unsuccessful. Owing to litigation and discouragement finally voted 166 to 14 to disorganize; dissolved by court April 18, 1896.	All indebtedness paid from time to time by assessments.
Voted $2,000,000 bond issue, made survey; traded $329,500 in bonds for water rights, rights of way, and services. Obtained decree of confirmation by fraud, which finally set aside and district declared null and void.	No settlement made or known to be contemplated.
Accomplished nothing and soon abandoned.	No record of any indebtedness.
Organized to take over existing canals, but three efforts to vote bonds failed and activities practically ceased in 1891 although kept alive and assessments levied for several years thereafter.	Running expenses paid from annual assessments; no debts left unpaid.
Exchanged $410,000 in bonds for '76 Canal and spent $133,000 for laterals. In litigation and other trouble to compromise in 1901, but never inactive. In later years system considerably improved and district now active and successful.	In order to stop litigation against the district and to aid and encourage the district, bondholders consented in 1901 to refund at 25 per cent discount.
Exchanged $250,000 in bonds for Kaweah and Settlers canals, and constructed connecting canal and laterals. Practically inactive and in much litigation 1895 to 1903, but again became active after compromise, and now successful. Now operated mostly by water tolls.	Original indebtedness, not including bond interest, compromised in 1902, mostly at 50 cents on dollar, money being raised by voluntary assessment and subscription.
Contracted for a completed system for practically entire bond issue, and this system, covering the entire area in district, was built. But when diversion of water attempted district permanently enjoined from taking any and district abandoned.	Indebtedness, not including paid interest, compromised in 1911 at average of 72 cents on dollar, money being raised by assessment of about 25 cents on $100 levied by supervisors.

STATISTICAL LIST OF IRRIGATION DISTRICTS ORGAN

Districts organized	County or counties in which located	Year organized	Area, acres (in most cases, approximate)	Bonded indebtedness incurred
Tule River	Tulare	1891	22,000	$100,000
Kern and Tulare	Kern and Tulare	1889	40,000	None
Poso	Kern	1888	40,000	$500,000
Neenach	Los Angeles	1893	3,840	None
Amargoza	Los Angeles	1895	5,000	None
Palmdale	Los Angeles	1890	50,000	None
Manzana	Los Angeles	1891	3,000	About $40,000
Little Rock Creek.	Los Angeles	1892	4,200 (including 1,300 acres government land not properly part of district)	Original, $88,000; later (for funding and reconstruction) $60,000.

IZED UNDER THE WRIGHT ACT OF 1887—Continued.

Extent of operations	Basis of financial settlement
Built dam in Tule River and reconstructed several existing systems, and when ready to distribute water injunction suits brought to restrain diversions by district and injunction granted December, 1898. Water delivered several years, but district soon went in state of stagnation and remained so until compromise. District disorganized January 20, 1913. Works built still in use by landowners.	Indebtedness, not including bond interest, compromised in 1904 at 50 cents on dollar, money being raised by district assessment voluntarily paid. Outstanding warrants, although long outlawed, also paid.
Voted $500,000 in bonds, but none issued. Spent about $40,000 in surveys, rights of way, and other preliminary expenses. Realizing injunction would be brought to prevent diversion from Kern River, voted to disorganize in 1896.	All money spent raised by assessments. After disorganization balance of $900 prorated among taxpayers.
After disposing of $60,000 in bonds contracted for a completed system from Poso Creek for remaining $440,000 voted. After partial completion of an inferior system realized no water available from Poso Creek and district abandoned.	Bonds mostly acquired by an investment company and land being released from bond liability by payment of $11 per acre, 16,715 acres having been so released by November, 1914.
Never active	No record of any indebtedness.
Made surveys, but soon abandoned	Expenses of organization and surveys paid by those most active.
Voted $175,000 bonds and did a little work looking to diversion from Little Rock Creek. Organization held null and void July 10, 1891, and abandoned. Some little development since by other parties.	No bonds issued. Outstanding warrants never paid.
Part of a land-selling scheme and accomplished nothing because no water available. Bonds traded for alleged water rights and part of a system. Abandoned early.	Several settlements proposed but none yet worked out.
Traded most of bonds disposed of to promoting company for water rights and construction. Little activity 1895 to about 1910 when compromise effected. Works reconstructed 1914–15 at cost of $35,000 in new bonds.	Old bond issue traded 1914 for $25,000 in new bonds.

STATISTICAL LIST OF IRRIGATION DISTRICTS ORGAN

Districts organized	County or counties in which located	Year organized	Area, acres (in most cases, approximate)	Bonded indebtedness incurred
Big Rock Creek	Los Angeles	1890	30,000	In excess of $223,000.
Santa Gertrudes	Los Angeles	1890	2,000	None
Vineland	Los Angeles	1889	4,000	$62,000
Glendora	Los Angeles	1892	3,000	None
Pomona Orange Belt.	Los Angeles	1890	4,000	$2,000
Strong	Los Angeles	1893	900	None
Walnut	Los Angeles	1893	869½	None
Rialto	San Bernardino	1890	7,200	About $411,000

IZED UNDER THE WRIGHT ACT OF 1887—Continued.

Extent of operations	Basis of financial settlement
Traded $150,000 bonds for water rights and ditch, partly going to promoting company. Additional bonds issued for miscellaneous expenses and additional water development. Abandoned because of no water. Small acreage now being irrigated.	No settlement. Suit on bonds pending November, 1914.
Voted $55,000 bonds, but unable to sell any. Lost water rights while wating. Disorganized September 16, 1899.	Old warrants, long outlawed, paid 50 cents on dollar.
Traded $10,000 for water rights and spent $50,000 in cash and bonds tunneling for water, but were enjoined from using the water developed, but about 100 inches obtained from well in district. Complete default since 1894. About 2,000 acres now being irrigated by small unincorporated company and district abandoned.	No settlement made or known to be contemplated October, 1914. Has about $1,500 still in treasury.
Voted $170,000 bonds, but none issued. District formed to take over Glendora Water Company and obtain additional supply from tunnels. Controversy over agreement followed by litigation in which bonds finally were declared illegal in 1896. Prior to this district abandoned and mutual company formed.	No record of any indebtedness.
Voted $200,000 bonds. Traded the $2,000 issued for water rights, which yielded one-tenth supposed supply. Plans abandoned early, but district not disorganized until 1897. Land now irrigated from wells.	Indebtedness paid in full by voluntary subscription.
Organized chiefly to get power of condemnation. Disputed water rights finally settled favorably and district activity ceased 1898.	Left no indebtedness.
Formed to reorganize and operate an existing ditch system. Has been continuously active and successful.	No settlement necessary; has always paid bills.
Organized to help sell land. Traded bonds disposed of to promoting company for supposed water right and a pipe system to be built. About 75 miles of pipe finally built and about 660 inches of water developed. With dry years water failed, and mutual company formed to operate system.	Over $200,000 of old bonds purchased at 12 to 25 cents on dollar by mutual company now operating system. Numerous suits and appeals on remaining bonds now pending, including appeals on judgments aggregating about $192,000.

STATISTICAL LIST OF IRRIGATION DISTRICTS ORGAN

Districts organized	County or counties in which located	Year organized	Area, acres (in most cases, approximate)	Bonded indebtedness incurred
Olive	San Bernardino	1893	900	None
Citrus Belt	San Bernardino	1890	11,700 (afterwards reduced to 2,450)	None
Grapeland	San Bernardino	1890	10,787	About $129,000
East Riverside	San Bernardino and Riverside.	1890	2,690	About $237,000
Alessandro	Riverside	1891	25,500	$765,000
Elsinore	Riverside	1889	15,000	None
Perris	Riverside	1890	25,000	Probably more than $400,000.
Murrietta	Riverside	1890	14,000	None

IZED UNDER THE WRIGHT ACT OF 1887—Continued.

Extent of operations	Basis of financial settlement
Voted $60,000 bonds to develop artesian water. After confirmation of bonds organizers decided to proceed differently and district disorganized.	Left no indebtedness.
Organized as adjunct to sale of lands. Trusteed $780,000 in bonds to cover development of water by promoting company and on failure of company bonds returned. Built about 1¼ miles ditch with warrants. Disorganized May 1, 1897. About 2,000 acres now watered.	All debts, mostly warrants, paid 50 cents on dollar.
Tapped underflow of Lytle Creek and built 10 to 15 miles of ditches. Organization held valid, but lost supposed water rights and ceased activity. Small area now supplied by development company.	No settlement yet. Suits over bonds pending. One judgment for $4,400 now on appeal to supreme court.
Developed some water from wells, purchased a pipe line for about $100,000 and built other works, mostly paid for in bonds. Reorganized into Riverside Heights Mutual Water Company and over $200,000 spent for betterments. Land all irrigated now.	Mutual company purchased most of bonds at about 25 to 50 cents on dollar. Bonds for $19,000 held invalid in federal court. A few bonds not yet located. Mutual company became responsible for all indebtedness.
Promoted by land and water company, to which it traded all of its bonds for "class B" water rights, the water system to remain the property of the promoting company. Part of the system agreed upon was built, but the company and the water supply both failed and district abandoned. District declared illegal.	No settlement. Bonds held void and bondholders declared to have had notice of illegality of issue. Final judgment acquiesced in by bondholders and bonds burned.
Investigated water supplies and voted $450,000 in bonds to buy "water rights" but abandoned before issuing bonds, owing to doubt as to ability to obtain water, and later dissolved by consent.	All indebtedness paid.
Voted $442,000 in bonds. Traded $240,000 in bonds for "class B" water rights and used nearly $200,000 in bonds in constructing distributing system in district. Promoting company and water supply failed and district abandoned.	In May, 1915, compromised claims on bonds and coupons, partly reduced to judgments, on basis of about 40 cents on dollar. Assumed that no further settlement likely on ground that bonds and coupons not sued on prior to January 1, 1915, have outlawed.
Looked for water in desultory way and bored one well, but was dissolved about five years after organization with nothing accomplished.	All indebtedness paid.

STATISTICAL LIST OF IRRIGATION DISTRICTS ORGAN

Districts organized	County or counties in which located	Year organized	Area, acres (in most cases, approximate)	Bonded indebtedness incurred
San Jacinto and Pleasant Valley.	Riverside	1891	18,000	$225,250
Riverside Heights.	Riverside	1891	1,400	None
Anaheim	Orange	1889	33,000	None
Escondido	San Diego	1889	12,814	$350,000
Fallbrook	San Diego	1891	12,000	None
Linda Vista	San Diego	1891	42,600	$176,000
Jamacha	San Diego	1891	22,000	$111,000
San Marcos	San Diego	1891	10,000	None
Otay	San Diego	1891	44,000	None

IZED UNDER THE WRIGHT ACT OF 1887—Continued.

Extent of operations	Basis of financial settlement
Voted $350,000 in bonds. Traded part for water rights and other property and sold some. Built 3 miles flume, 18 miles main and 12 miles lateral ditches. Irrigated a few hundred acres. Found water and system inadequate and district declared void and abandoned.	No settlement. Some bond claims reduced to judgments, but these not satisfied, and no settlement plan known to be pending. District said to consider itself only liable for about $65,000 of bonds sold for cash.
Voted $300,000 in bonds, but none issued. Spent about $3,000 for general expenses and about $15,000 developing water. Found not feasible and abandoned.	All debts paid before district abandoned.
Voted $600,000 in bonds and proposed to take over and improve local systems, but finally abandoned and dissolved September 12, 1895.	All debts paid before dissolution.
Built dam, tunnels, flumes, and ditches and distributed water to about 1,000 acres. Then changed to mutual company and since operated as such. Dissolved.	Compromised by paying bondholder $200,000 and interest thereon for a few months in full settlement of claims aggregating $498,365 on January 1, 1905.
Voted $400,000 in bonds, but sold none and did nothing beyond preliminary investigation. Declared not legally organized.	No record of having left any indebtedness.
Voted $1,000,000 in bonds. Traded most of those disposed of to the promoters for supposed water properties and paid $10,000 for certain water rights. Dissolved April 15, 1914.	Exchanged water properties originally acquired with $176,000 in bonds for $55,000 of old bonds and compromised remainder of the debt for $125,000 raised by district assessment in 1913 and 1914.
Voted $700,000 in bonds. Purchased Barrett dam site and related water rights for $105,000 in bonds. Adverse conditions resulted in abandonment. Subsequently all property acquired exchanged for all outstanding bonds and warrants and district dissolved May 5, 1909.	All debts paid before dissolution. (See preceding column.)
Voted $350,000 in bonds, but after examination of probable cost was voted to disorganize. Dissolved by court October 4, 1893.	All indebtedness paid before dissolution.
Proposed to utilize Moreno dam site, but got into litigation and abandoned. Incurred expenses to amount of about $6,000. Levied one assessment of $9,000, but this held invalid. Voted to dissolve in 1894, but dissolution not allowed because of outstanding debts.	No settlement. All debts outlawed.

II.

LIST OF IRRIGATION DISTRICTS, PROPOSED UNDER THE ORIGINAL WRIGHT ACT, FOR WHICH ORGANIZATION WAS NEVER COMPLETED.

Records of the old Wright act districts disclose a number of attempts to form districts that were not successful. In some cases the petitions to the supervisors were denied; in other cases they were withdrawn. In at least one case there has been merely a confusion of names. As some of these proposed districts have occasionally been referred to as districts that were fully organized, a list of them, together with statements of essential facts regarding them, is included herewith:

Spring Valley (San Diego County).—This was merely the name originally proposed for Jamacha district.

Oceanside Coast (San Diego County).—Petition filed September 12, 1891; denied October 5, 1891.

Azusa (Los Angeles County).—Petitions filed April 1, 1889, June 10, 1889, and at one later time. At one election on the proposal to organize 181 voted "Yes" and 111 "No." Plan definitely abandoned July 28, 1890.

Downey (Los Angeles County).—Petition filed January 5, 1888. Remonstrance filed January 20, 1888. Dropped.

Alhambra (Los Angeles County).—Petition filed August 3, 1889. Approved by supervisors but withdrawn at request of petitioners.

Acton (Los Angeles County).—Petition filed December 26, 1892. Protest filed saying project would bond lands included for one-half of their value and that the promoters would get the benefit. Petition dismissed April 19, 1893.

Delhesa (Los Angeles County).—Petition filed March 9, 1891; denied April 3, 1891.

Willows (Colusa County).—Petition filed December 8, 1887. Organization defeated at election January 14, 1888, vote standing 88 for and 48 against. As originally proposed this district included some land in Orland Southside district but this was excluded prior to the election.

College (Colusa County).—Petition filed May 7, 1888. Organization defeated by vote of 74 to 43 at election held June 18, 1888. Covered land near College City southeast of Colusa, water to be taken from Sacramento River.

Pierce (Colusa County).—Petition filed August 6, 1888. Covered land south of Willows. Organization defeated September 8, 1888, by vote of 61 to 34.

Kirkwood (Tehama County).—Petition filed December 24, 1889. Water for district to be obtained from Toms Creek. Organization defeated by vote of 20 to 39 January 20, 1890.

III.

LIST OF IRRIGATION DISTRICT CASES AFFECTING CALIFORNIA IRRIGATION DISTRICTS AND SUBJECTS DEALT WITH IN DECISIONS.

Turlock Irrigation District vs. **Williams,** 76 Cal. 360, May 31, 1888: Constitutionality; public nature of irrigation districts; assessments; condemnation.

Central Irrigation District vs. **De Lappe et al.,** 79 Cal. 351, May 31, 1889: Bonds; constitutionality; public nature of irrigation districts; organization; construction of law; petition; sufficiency of bond; meeting of board; publication of petition; establishment of boundaries; publication of election proclamation; establishment of voting precincts; form of bonds.

Crall vs. **Board of Directors of Poso Irrigation District,** 87 Cal. 140, December 15, 1890: Constitutionality; public nature of irrigation districts; bonds; confirmation proceedings; jurisdiction of court therein; service of process.

Board of Directors of Modesto Irrigation District vs. **Tregea,** 88 Cal. 334, March 19, 1891: Bonds; confirmation proceedings; publication of notice of petition; contents of notice; jurisdiction of court after amending petition; inclusion of city lands; sale of allotted water; judgment of board on inclusion; materiality of evidence of fraud; exclusion of lands; reintroduction of evidence; notice of election; time of commencing proceeding; effect of exclusion on subsequent bonds.

Palmdale Irrigation District et al. vs. **Rathke et al.,** 91 Cal. 538, October 14, 1891: Bonds; confirmation proceedings; appeal; notice of entry of judgment; estoppel by stipulation.

In re Bonds of Madera Irrigation District, 92 Cal. 296, December 14, 1891: Constitutionality; public use; organization of public corporations; public nature of irrigation districts; taxation; assessments for local improvements; sufficiency of bond accompanying petition; sufficiency of boundary description; proof of presentation of petition; form of bonds; inclusion of municipality.

People vs. **Turnbull,** 93 Cal. 630, March 17, 1892: Attempted bribery; scope of "Trustee" in Penal Code; allegation of *quasi* public nature of corporation.

Tregea vs. **Owens,** 94 Cal. 317, April 11, 1892: Assessment; taxation; authorization of assessment by electors.

People vs. **Selma Irrigation District,** 98 Cal. 206, May 4, 1893: Public nature of irrigation districts; dissolution for nonuser of franchise.

Sanford vs. **East Riverside Irrigation District,** 101 Cal. 275, February 7, 1894: Contract; damages; findings on conflicting evidence; ascertainment of profit.

Quint vs. **McMullen,** 103 Cal. 381, July 20, 1894: Quieting title; delinquent tax sale; erroneous decree; status of ownership.

Rialto Irrigating District vs. **Brandon et al.,** 103 Cal. 384, July 20, 1894: Condemnation; authority to construct pipe line; confirmation proceeding.

Quint vs. **Hoffman et al.,** 103 Cal. 506, August 8, 1894: Assessments; *de jure* or *de facto* character of district; collateral attack on validity of organization; payment of just tax.

Woodruff et al. vs. **Perry et al.,** 103 Cal. 611, August 25, 1894: Assessment; authorization by electors.

Directors of Fallbrook Irrigation District vs. **Abila,** 106 Cal. 355, 365, March 11, 1895: Confirmation proceedings; qualifications of signers of petition for organization; tenant in common; married woman holding community property as signer; holder of certificate of purchase from state for school land partly paid for as signer; issues in new trial; time of opening and closing polls; burden of proof in confirmation proceedings; bonds; entry on minutes of board; rescission of resolution for bond issue.

First National Bank of Bridgeport, Ohio, vs. **Perris Irrigation District et al.,** 107 Cal. 55, April 5, 1895: Notice by materialman; assignment by contractor; rights of *bona fide* assignee; voidability of executed contract; filing of notice of claim; entirety of contract; value of patterns; counterclaim; setoff.

City of San Diego vs. **Linda Vista Irrigation District et al.,** 108 Cal. 189, July 19, 1895: Assessment and taxation; pueblo lands of city; state lands; government lands.

Fudickar vs. **East Riverside Irrigation District,** 109 Cal. 29, September 5, 1895: Allegation of ownership; real property character of water right; president of corporation as grantor and grantee; voidability of unauthorized conveyance; enforcement of voidable contract against assignee.

Cooper vs. **Miller et al.,** 113 Cal. 238, June 6, 1896: Assessment; sale; assessment of several lots in one parcel; double levy in one order; tax deed as evidence of election; recital of election in order of board; materiality of allegation of payment.

Cullen et al. vs. **The Glendora Water Company,** 113 Cal. 503, July 25, 1896: Confirmation proceedings; plans and estimates; constitutionality of act of 1889; sufficiency of boundary description; inclusion and exclusion of land; divisions in district; election of directors; fraud in organization; inclusion of railroad lands.

Hughson et al. vs. **Crane,** 115 Cal. 404, December 18, 1896: Bonds; assessments; discretion of board in making levy; *bona fides* of bondholders; district as party in action to vacate assessment.

Boehmer vs. **Big Rock Irrigation District et al.,** 117 Cal. 19, May 14, 1897: Proof of ownership; riparian rights; percolating waters; procedure for new trial; right of district to sue and be sued.

Wilson et al. vs. **Carter,** 117 Cal. 53, May 21, 1897: Assessment; sale; liability of former collector.

In re Organization and Bonds of the Central Irrigation District, 117 Cal. 382, June 24, 1897: Confirmation act; special proceeding; weight of prior decision; finality of supervisors' decision; constitutionality; publication of notice of presenting petition; freeholders; owners of town lots as petitioners; bonds; rights of *bona fide* bondholders.

Carter vs. **Tilghman,** 119 Cal. 104, November 24, 1897: Warrants, assessments; division into funds.

Mitchell vs. **Patterson,** 120 Cal. 286, March 15, 1898: Warrants; clerical errors in findings; statutory funds of district; liability for salaries and expenses.

Lahman et al. vs. **Hatch,** 124 Cal. 1, March 9, 1899: Assessments; description in assessment book; alterations by board of equalization; constitutionality; notice of levy.

Hewitt et al. vs. **San Jacinto and Pleasant Valley Irrigation District et al.,** 124 Cal. 186, April 3, 1899: Water rights; delivery of water; usage in community; proof of land ownership; assumption of contracts by district; delivery of water outside district; introduction of evidence; damages to crops.

People ex rel. Stone vs. **Jefferds et al.,** 126 Cal. 296, October 12, 1899: Dismissal of action; laches of irrigation district; discretion of judge.

East Riverside Irrigation District vs. **Holcomb et al.,** 126 Cal. 315, October 18, 1899: Proper parties; intervention; cross-complaint on new cause of action.

Vineland Irrigation District vs. **Azusa Irrigating Company et al.,** 126 Cal. 486, October 28, 1899: Appropriation of water; notice of appropriation; surface flow; subterranean flow; "percolating waters" defined; change of point of diversion.

Perry vs. **Otay Irrigation District et al.,** 127 Cal. 565, February 15, 1900: Public character of district officers; assessments; set-off of salary; public funds; illegality of collection.

People vs. **Linda Vista Irrigation District,** 128 Cal. 477, May 3, 1900: Confirmatory act; purpose of special proceeding; constitutionality of confirmatory act; scope of judgment in special proceeding; bar to subsequent *quo warranto;* public nature of irrigation districts.

Sechrist et al. vs. **Rialto Irrigation District et al.,** 129 Cal. 640, September 5, 1900: Demurrers; bonds; statute of limitations; laches; relief of taxpayer without first doing equity; district as plaintiff and defendant; proper and necessary parties.

Escondido High School District of San Diego County vs. **Escondido Seminary of University of Southern California et al.,** 130 Cal. 128, September 27, 1900: Assessments; misnomer of owner of property assessed; conclusiveness of tax deed; discretion of board of directors in making levy; contents of tax deed; constitutionality.

Kerr vs. **Superior Court,** 130 Cal. 183, October 2, 1900: Mandamus; review of action of court; citation; discretion of court; undertaking of fruitless thing.

People ex rel. Fogg vs. **Perris Irrigation District,** 132 Cal. 289, March 21, 1901: Rights of intervenors on appeal; confirmation proceedings; impeachment of confirmation judgments.

Stimson vs. **Alessandro Irrigation District,** 135 Cal. 389, January 23, 1902: Powers of boards of directors; bonds delivered for executory contract; jurisdiction of court in special proceeding.

Baxter vs. **Vineland Irrigation District et al.,** 136 Cal. 185, April 3, 1902: Bondholders as proper parties; collateral attack on bonds; rights of *bona fide* holders; assessments; acts of *de facto* officer; sale noticed for legal holiday; proof of allegations in complaint.

Nevada National Bank of San Francisco vs. **Poso Irrigation District,** 140 Cal. 344, September 25, 1903: Government lands; liability of patented land on bonds previously issued; inclusion of patented land.

Henry et al. vs. **Vineland Irrigation District et al.,** 140 Cal. 376, September 28, 1903: Assessments; dismissal of action; effect on intervenor.

Leeman vs. **Perris Irrigation District,** 140 Cal. 540, October 9, 1903: Bonds; authority of board to dispose of bonds; *bona fides* of holder.

Turpen vs. **Turlock Irrigation District et al.,** 141 Cal. 1, October 17, 1903: Condemnation; damage from seepage; reasonableness of construction work.

People vs. **Perris Irrigation District,** 142 Cal. 601, March 26, 1904: Notice of appeal; statute of limitations; fraud; special proceeding; effect of special proceeding on validity of organization; cause for action in equity.

Merchants' National Bank of San Diego vs. **Escondido Irrigation District,** 144 Cal. 329, August 3, 1904: Pledge of district property; constitutionality; public and private nature of irrigation districts.

Boskowitz et al. vs. **Thompson et al.,** 144 Cal. 724, September 20, 1904: Rights of intervenors; liens; assessments; judicial power to declare and enforce liens; discretion of board of directors.

Best vs. **Wohlford et al.**, 144 Cal. 733, September 20, 1904: Tax-deed assessment; description of land assessed; parol evidence on description; reference to map.

Jenison vs. **Redfield et al.**, 149 Cal. 500, July 30, 1906: Ownership of proportionate share of district water; use of water outside district; damages; prescriptive right of landowner against district.

Western Union Telegraph Company vs. **Modesto Irrigation Company et al.**, 149 Cal. 662, August 31, 1906: Assessments; real property; personal property; telegraph lines.

Best vs. **Wohlford et al.**, 153 Cal. 17, February 8, 1908: Assessments; tax deed; sufficiency of description of land; least quantity of land; time when entitled to deed; abbreviations in notice of sale; statement of separate assessments.

Fogg vs. **Perris Irrigation District**, 154 Cal. 209, August 28, 1908: Notice and petition; fraud in organization; voidability of organization; decree of confirmation; contents of notice of hearing; changes in boundaries; bonds; effect of invalid and valid decrees.

De La Beckwith vs. **Sheldon et al.**, 154 Cal. 393, October 13, 1908: Appropriation; lease from district; contract; confidential relations of contractors; place of diversion; prosecution of work under notice of appropriation; admissibility of evidence; magnitude of enterprise; lapse of district's rights; proper parties.

Tulare Irrigation District et al. vs. **Collins**, 154 Cal. 440, October 20, 1908: Execution sale; public trust; estoppel of district.

Stowell vs. **Rialto Irrigation District**, 155 Cal. 215, February 17, 1909: Contract to deliver bonds; purposes of bond exchange; form of bonds; negotiability.

Chinn et al. vs. **Superior Court of San Joaquin County**, 156 Cal. 478, November 19, 1909: Judicial power of courts; appeals from board of supervisors; constitutionality.

Walnut Irrigation District vs. **Burke et al.**, 158 Cal. 165, 168, August 1, 1910: Appeals; place of use of water; prior rights; use of water within district; rules of water delivery.

Haese vs. **Heitzeg**, 159 Cal. 569, March 16, 1911: Assessment; delinquent tax deed; good faith of district; stipulation; parties bound by judgment *in personam;* confirmation proceeding; *de facto* corporation; rights of *bona fide* holders.

In re Bonds of the South San Joaquin Irrigation District, 161 Cal. 345, November 15, 1911: Constitutionality; effect of unconstitutionality of one provision on entire act; title of act.

Imperial Water Company No. 1 vs. **Board of Supervisors of Imperial County et al.**, 162 Cal. 14, January 8, 1912: Writ of review; creation

of public corporations; judicial character of board of supervisors; constitutionality of section and of entire act; signatures to notice of petition; contents of notice; due process of law; proof of publication; evidence on signatures; qualifications of petitioners; inclusion of lands; consideration of evidence on *certiorari*.

De La Beckwith vs. **Sheldon et al.**, 165 Cal. 319, April 16, 1913: Novation; substitution of contract; revival of canceled contract; effect of new contract; effect of intervening rights.

Imperial Land Company et al. vs. **Imperial Irrigation District et al.**, 166 Cal. 491, December 8, 1913: *Mandamus;* assessment; election petition; concurrent jurisdiction of superior court.

De La Beckwith vs. **Sheldon**, 168 Cal. 742, December 10, 1914: Construction of contract; allegation of value of bonds; lien on property of company.

Decker vs. **Perry**, 35 Pac. 1017, February 28, 1894: Illegal assessment; election; payment under protest; averment of district organization.

Hewel vs. **Hogin**, 84 Pac. 1002, November 17, 1905; March 15, 1906: Permission to amend; lithographic signature; funds for payment of bonds; *mandamus;* interest on interest coupons; statute of limitations.

Healey et al. vs. **Anglo-Californian Bank, Limited, et al.**, 90 Pac. 54, March 27, 1907: Bids for construction; forfeiture; notice for bids; plans and specifications.

Nevada National Bank of San Francisco vs. **Board of Supervisors of Kern County et al.**, 91 Pac. 122, May 28, 1907: Jurisdiction of superior court; levy by supervisors *vice* directors; expenses of levy; erroneous direction in decree; effect of judgment on litigated obligation; constitutionality; time of levy by supervisors; provision for other creditors; laches.

Commercial National Bank of Ogden vs. **Schlitz**, 91 Pac. 750, July 31, 1907: Filing of notice to move for new trial; assessments; dissolution; delinquent tax deed; description of property; prescription as affected by payment of taxes.

McPherson vs. **Alta Irrigation District et al.**, 112 Pac. 193, October 18, 1910: *Res adjudicata;* new issue in appellate court; acquiescence of plaintiff in existing conditions.

Harelson vs. **South San Joaquin Irrigation District et al.**, 128 Pac. 1010, November 8, 1912: Inclusion of lands; "another source" of irrigation defined; estoppel of landowner on exclusion; limits of discretion of board; *mandamus* as remedy.

Nahl vs. **Alta Irrigation District et al.**, 137 Pac. 1080, November 22, 1913: Maintenance of irrigation ditch; duty of owner; degree of care required; liability for extraordinary floods.

Byington et al. vs. **Sacramento Valley West Side Canal Company et al.,** 148 Pac. 790, April 29, 1915: *De facto* character of district; illegal organization; dissolution; public use; estoppel to deny title of lessor; *ultra vires* lease; transfer of franchises; constitutionality; administration of public use; *mandamus;* protection of incipient right; public service corporation; preferential water rights; subversion to private use.

FEDERAL CASES.

Bradley et al. vs. **Fallbrook Irrigation District et al.,** 68 Fed. 948, July 22, 1895: Relief in equity; constitutionality; public use; due process of law.

Miller vs. **Perris Irrigation District et al.,** 85 Fed. 693, February 21, 1898: Corporate existence; challenge by private parties; effect of state decisions on federal courts; conclusiveness of confirmation decrees; statutory bar to attack on illegality of organization; accrual of cause of action.

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Shepard vs. **Tulare Irrigation District,** 94 Fed. 1, April 24, 1899: *Mandamus;* federal jurisdiction; bond fund; demand on county treasurer; allegations of regularity in issuance.

Herring vs. **Modesto Irrigation District,** 95 Fed. 705, June 30, 1899: Allegation of failure to perform duty; jurisdiction of federal courts; *mandamus;* constitutionality; decisions of California courts; corporate character of district; estoppel of district to plead illegal organization; construction of statute of limitations; discretion of supervisors; effect of exclusion of lands on bonds.

Miller vs. **Perris Irrigation District et al.,** 99 Fed. 143, January 15, 1900: Estoppel of municipality; rights of *bona fide* bondholders; duty of directors; binding force of judgment in special proceeding; effect of *quo warranto* on bonds.

Perris Irrigation District vs. **Thompson,** 116 Fed. 832, May 5, 1902: Relief of bondholder; purport of confirmation proceedings; bonds as evidence of corporate character; president of district as bondholder.

Thompson vs. **Perris Irrigation District,** 116 Fed. 769, June 11, 1902: *Mandamus;* duty of supervisors; remedy of bondholders.

People ex rel. Brady vs. **Browns Valley Irrigation District et al.,** 119 Fed. 535, November 3, 1902: *Quo warranto;* constitutionality.

Board of Supervisors of Riverside County et al. vs. **Thompson et al.,** 122 Fed. 860, May 11, 1903: Levy by supervisors; *res adjudicata; mandamus;* notice to supervisors; effect of act of 1897 on districts previously organized; competency of petition to supervisors as evidence.

Marra vs. **San Jacinto and Pleasant Valley Irrigation District et al.,** 131 Fed. 780, April 27, 1904: Receivership; remedy on bonds; *mandamus.*

Wright vs. **East Riverside Irrigation District,** 138 Fed. 313, May 29, 1905: *Bona fide* bondholders; signatures to bonds; signatures to coupons; antedating.

Quinton et al. vs. **Equitable Investment Company et al.,** 196 Fed. 314, May 6, 1912: Relief in equity; vacancies in office; powers of taxpayers; collateral attack on organization.

Perris Irrigation District vs. **Turnbull,** 215 Fed. 562, May 4, 1914: Issuance of summons; following state procedure.

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Fallbrook Irrigation District vs. **Bradley,** 164 U. S. 112, November 16, 1896: Constitutionality; authority of state courts; due process of law; public use; hearing before supervisors; public nature of irrigation districts; assessments.

Tregea vs. **Modesto Irrigation District,** 164 U. S. 179, November 16, 1896: Confirmation proceeding; adjudication therein; *res adjudicata.*

Tulare Irrigation District vs. **Shepard,** 185 U. S. 1, March 24, 1902: Notice and petition; corporate character of district; rights of *bona fide* bondholders; recital in bonds; determination of board of supervisors.

IV.

OUTLINE OF CALIFORNIA IRRIGATION DISTRICT ACT OF 1897 AS AMENDED TO 1915.

(For substance of supplemental acts and constitutional amendments, *see* discussion in main text on "Irrigation District Legislation Since the Act of 1897," p. 47.)

ORGANIZATION.

Who may sign organization petition.

SECTION 1. A majority in number of holders of title or evidence of title, including holders of possessory rights, to lands susceptible of irrigation from a common source and by the same system of works, representing majority in value of said lands, may propose the organization of an irrigation district. Such lands need not consist of contiguous parcels. Owners of undivided interests may sign for such interest and each such owner shall be considered as one assessment payer. Guardians, executors, administrators, or other persons holding property in a trust capacity under appointment of court may sign any petition provided for in the act, when authorized to do so by order of court.

Hearing on petition; report by State Engineer.

SEC. 2. Petition to be filed with supervisors and to set forth generally proposed boundaries and proposed water source or sources. Must be accompanied by undertaking, to be approved by supervisors, in double amount of probable cost of organizing and be presented at regular meeting, and also be published in some newspaper of general circulation printed and published in county where presented, together with notice stating time of meeting at which petition is to be considered. On or before day petition is presented to supervisors, copy thereof to be filed with State Engineer. Supervisors to determine sufficiency and regularity of petition within two weeks. If necessary legal requirements not complied with in petition, matter to be dismissed without prejudice. If supervisors determine that all requirements have been complied with in petition, copy of resolution so declaring to be forwarded to State Engineer, and further hearing postponed not exceeding one month in all. Upon receiving copy of resolution State Engineer to make such investigation as may be practicable, with view to determining whether any condition or conditions exist that would justify him in reporting against organization. State Engineer to report in writing within one month. If he reports that proposed project is not feasible, hearing of petition by supervisors shall again be continued, not exceeding one month, and petition shall then be dismissed, unless supervisors be requested in writing by three-fourths of holders of title or evidence of title to grant it; *provided*, that supervisors may modify proposed plans in accordance with recommendations of State Engineer. Failure of State Engineer to report, however, shall not invalidate organization of any district. On final hearing supervisors shall make any changes in proposed boundaries that are deemed advisable, but shall not exclude any land susceptible of irrigation from any of the sources proposed, nor include any lands which will not be benefited by irrigation from the proposed system of works. Any person whose lands are susceptible of irrigation from proposed sources may, in discretion of supervisors, be included.

Final hearing by supervisors.

SEC. 3. Upon final hearing supervisors reaffirm conclusions as to sufficiency of petition. Only new evidence against sufficiency to be heard.

SEC. 4. Finding in favor of sufficiency final against all except state of California, and suit by state must be brought within one year.

Divisions and representation for directors.

SEC. 5. At final hearing supervisors divide district into three or five divisions, as determined by petition. One director to represent each division and reside therein, but may be elected by divisions or at large, as provided in petition.

Election on organization.

SEC. 6. Notice of election on organization given by supervisors and published three weeks. Supervisors also establish election precincts. Election to be conducted as nearly as practicable in accordance with general election laws.

Officers to be elected.

SEC. 7. At organization election there shall be elected directors, assessor, tax collector, and treasurer. If petition so requests certain offices may be consolidated.

Qualifications of electors.

SEC. 8. No person shall be entitled to vote at any election held under the provisions of this act who does not possess all of the qualifications required of electors under the general election laws of the state.

Canvass of vote; filing order; contests.

SEC. 9. Supervisors canvass vote on second Monday succeeding organization election. Two-thirds vote required to carry organization. Candidates for offices receiving highest number of votes are elected.

SEC. 10. Supervisors file order on organization and election officers, after which organization complete. Thereafter, no lands embraced in district can be included in another district without consent of directors.

SEC. 11. Organization election may be contested in superior court within twenty days after canvass of vote. Appeal may be taken within thirty days from judgment and must be decided by supreme court within sixty days.

SEC. 12. Officers elected immediately enter on duties.

Organization of directors.

SEC. 13. On first Tuesday after election directors classify themselves by lot and two or three (depending on whether three or five elected) serve until next, and the others until the second, general February election. Elect president from their number and appoint secretary, each to serve during pleasure of directors. Directors fix salary and bond of secretary.

MANAGEMENT.

Meetings of directors; financial statement.

SEC. 14. Directors to hold regular monthly meetings at their office at time fixed by resolution. Time can not be changed for twelve months and then only two months after resolution ordering change and after publication of notice. Directors may hold special meetings. All meetings of directors and all records open to public. Majority of directors constitute quorum. At regular meeting in January of each year directors shall render and thereafter publish verified financial statement. Whenever act specifies first Tuesday in month for transaction of any business, regular monthly meeting may be substituted; and when regular monthly meeting is other than first Tuesday, new boards of directors shall organize at first regular meeting in March.

Powers of officers; limitations on indebtedness; by-laws; rules and regulations.

SEC. 15. Directors manage business affairs of district, make necessary contracts, employ agents, officers, and employees, and prescribe their duties. Directors and their employees may enter any land and make surveys; acquire by purchase, lease, or condemnation necessary rights and properties including canals and works constructed and being constructed, and stock of other corporations owning water properties; but no purchase in excess of ten thousand dollars can be made without prior petition by majority of owners representing majority in value of lands in district. Directors may also construct necessary works and perform any necessary lawful act that sufficient water may be furnished, take conveyances or contracts for property acquired, institute and maintain necessary actions, sue and be sued. Directors shall establish and print by-laws and rules and regulations. Shall have power generally to perform all necessary acts.

Change of boundaries of divisions and precincts; lease of works.

SEC. 15½. Directors may change boundaries of divisions and election precincts, but not less than sixty days prior to an election. May also lease works of district, or any part thereof, but only after prior publication for three weeks of intention to lease, and only to highest bidder, from whom bond shall be required.

Condemnation.

SEC. 16. Suits for condemnation to be brought under title seven, part three, Code of Civil Procedure.

USE OF WATER.

Public use.

SEC. 17. Use of water for irrigation of lands within any district and for domestic and other incidental beneficial uses within district, and rights of way necessary declared a public use subject to regulation and control of state.

Prorating of water.

SEC. 18. All waters distributed for irrigation purposes to be prorated to landowners on basis of assessments for district purposes; and any landowner may assign whole or portion of his apportionment.

GENERAL ELECTIONS.

Time; officers to be elected; bonds; special elections when default in general election; organization of board; term of office.

SEC. 19. General elections to be held on first Wednesday in February each second year after 1899, and assessor, collector, treasurer, and directors elected. Assessor, collector, and treasurer to hold office for two years. Assessor to execute bond for five thousand dollars, collector for not more than twenty thousand or less than five thousand dollars, treasurer for not more than fifty thousand or less than ten thousand dollars, and directors for five thousand dollars each. Where district appointed fiscal agent of United States additional bonds may be required by secretary of interior. If general election not held as provided, special election shall be called on petition of ten per cent of resident electors.

SEC. 20. Directors organize on first Tuesday in March following election. Term of office of directors is four years.

Notice and conduct of general elections; nominations; vacancies; qualifications of directors; consolidation of offices; number of directors and representation; recall.

SEC. 21. Notice of general election to be posted fifteen days prior to election. Directors to appoint election officers.

SEC. 22. Inspector is chairman of election board and may administer oaths, etc. Polls open 8 a.m. to 4 p.m.

SEC. 22*a*. Ballots to be provided by directors; form of ballot; voting.

SEC. 22*b*. Not less than ten days before an election ten or more electors may make nominations by petition.

SEC. 23. Voting conducted as nearly as practicable according to general election laws; counting of ballots; returns of election; recount.

SEC. 24. Directors publicly canvass election returns first Monday after election and declare result.

SEC. 25. Secretary records election returns, directors declare result, and secretary issues election certificates. In case of vacancy in office of assessor, collector, or treasurer, directors appoint, and if directors fail to fill vacancy within forty days, supervisors shall. In case of vacancy in board of directors, supervisors appoint. All officers appointed to fill vacancies serve until next regular election.

SEC. 26. A director shall be a resident and a freeholder of the district.

SEC. 27. Directors may consolidate or segregate offices of assessor, collector, and treasurer, provided consolidation or segregation is made thirty days prior to general election.

SEC. 28. On petition by a majority of owners, directors may order that at ensuing election either three or five directors shall be elected, and that they shall be elected by divisions or at large, but directors elected at large must nevertheless represent separate divisions and reside therein.

SEC. 28½. Any elective officer can be recalled at any time, recall petition to be signed by twenty-five per cent of highest vote cast for candidates at last general district election, and if elected by division, by twenty-five per cent therein. If petition sufficient, election called for between thirty-five and forty days later, or at general election if one to occur within between thirty-five and sixty days. Nominations of candidates for recall elections to be made as other nominations. Vote for candidate not counted unless voter voted on recall. Majority vote determines result. Procedure identical with that in regular election. If recall unsuccessful no further petition allowed within six months.

TITLE TO AND SALE OF PROPERTY.

SEC. 29. Title to all property acquired by district shall vest in district and be held in trust for it and is dedicated to the uses and purposes set forth in the act. Directors authorized to hold, use, acquire, manage, occupy, and possess such property, and may sell property no longer necessary.

ISSUANCE OF BONDS.

Estimate by directors; report by State Engineer; vote; form and term of bonds; interest rate; sale of bonds; price.

SEC. 30. Directors estimate and determine amount of money necessary to be raised and for that purpose shall make all needed surveys and plans under direction of competent irrigation engineer. Copy of engineer's report to be sent to State Engineer, who shall examine and make further examinations necessary and report to directors within ninety days, giving his conclusions as to the supply of water available and the feasibility of the project. Directors then, when petitioned by majority of owners, representing majority in value of lands, shall call election on bond issue. Notice of election must be given for twenty days. Election to be held as nearly as practicable in conformity with provisions governing election of officers. Alternative questions as to issuance of bonds may be submitted separately on same ballot. Majority vote required to carry bonds.

SEC. 31. Bonds payable in twenty series—two per cent at end of twenty-one years and twenty-two years; three per cent at end of twenty-three years and twenty-four years; four per cent at the end of twenty-five years, twenty-six years, twenty-seven years, and twenty-eight years; five per cent at the end of twenty-nine years, thirty years, thirty-one years, and thirty-two years; six per cent at the end of thirty-three years, thirty-four years, thirty-five years, and thirty-six years; seven per cent at the end of thirty-seven years and thirty-eight years; eight per cent at the end of thirty-nine years and forty years; provided that if so specified in petition, bonds may be in less than twenty series and be payable at end of shorter periods. Bonds bear interest at not to exceed six per cent, payable January 1 and July 1. Denomination not less than one hundred nor more than one thousand dollars, and bonds are negotiable.

SEC. 32. Directors may sell bonds as necessary but only after resolution and advertisement, and must go to highest bidder, or any or all bids may be rejected.

SEC. 32½. Bonds authorized before amendment of 1913 removing par limit but not sold may be sold for less than par if approved at special election by two-thirds vote.

Payment of bonds.

SEC. 33. Bonds and interest thereon to be paid from annual assessments on real property of district, and all such real property liable to assessment for such purpose. (*See* exemption of improvements, section 35.)

Special assessment to complete works if funds insufficient.

SEC. 34. If money raised from bond sales be insufficient for completing works, and more bonds not voted, directors shall levy assessment for such purpose if approved by majority vote at a special election.

ASSESSMENTS.

Duties of assessors; deputy assessors; equalization; levy and collection; lien.

SEC. 35. Assessment of all real estate in district to be made between first Monday in March and first Monday in June at full cash value, except that improvements, including trees, vines, alfalfa, and all growing crops and all buildings and structures erected or being erected, are exempted. In districts organized prior to amendment exempting improvements, improvements may be exempted at special election by vote of majority of resident owners of land subject to taxation therein.

SEC. 36. Assessor shall be allowed necessary deputy assessors at not to exceed five dollars per day.

SECS. 37 and 38. Assessor must deliver completed assessment book to secretary on or before first Monday in August, who shall give notice of equalization, to be made within between twenty and thirty days. Equalization shall be made by directors during session of not to exceed ten days, and within ten days thereafter secretary must have roll corrected and totaled.

SEC. 39. Within fifteen days after equalization directors shall levy assessment to cover interest and principal due on bonds, rentals or charges due or to come due during year on leases or contracts, and amount due on any obligation reduced to judgment. If directors fail to make assessments and levies, county assessment shall be used and supervisors shall make levy at expense of district. On failure of district collector or treasurer to act, county tax collector and assessor shall do so. Is duty of district attorney to ascertain each year whether necessary assessments have been levied and collected, and if there has been neglect or refusal by district officers, district attorney shall notify county officers authorized to act and upon their failure to act within thirty days shall take appropriate action in court to compel performance. For enforcement of levy and collection of assessment levied after adoption of amendment so providing, and to pay debt incurred after adoption of such amendment, attorney general of state shall take appropriate action on failure of district and county officers to act. All powers and duties respecting collection of assessments provided in sections 3820, 3821, 3822, 3823, 3824, 3825, and 3829 of the Political Code, as regards county assessors, shall apply as far as applicable to irrigation district assessors.

SEC. 40. Unpaid assessments become a lien after first Monday in March (*see* Stats. 1913, chap. 274, p. 415, relating to collection of assessments in two installments) and lien for bonds of any issue shall be a preferred lien to that for any subsequent issue.

Delinquencies; penalties; publication of delinquent notice sale.

SEC. 41. On or before November first assessment book delivered to collector and within twenty days collector must give notice that assessments are due and will become delinquent at 6 p.m. on last Monday in December. (*See* Stats. 1913, chap. 274, p. 415, relating to collection of assessments in two installments.) Ten per cent penalty added if not paid within time specified.

SEC. 41*a*. In lieu of selling property on delinquent list directors may direct collector to sue delinquent for amount due, in accordance with Code of Civil Procedure.

SEC. 42. Collector must publish delinquent list on or before February first, and time of sale specified in notice must be not less than twenty-one nor more than twenty-eight days from first publication.

SEC. 43. In addition to principal and ten per cent penalty, collector must collect fifty cents on each tract separately assessed and sale must be completed within three weeks.

SEC. 44. In case there is no purchaser in good faith for property offered for sale, whole amount of property assessed shall be struck off to district.

SEC. 45. Collector shall issue certificates of sale, in duplicate, one copy to be given to purchaser and one copy to be filed in office of county recorder.

SEC. 46. Secretary must enter in his records a description of land sold and on filing of certificate with county recorder, lien of assessments vests with purchaser and is only divested by payment of purchase price and two per cent per month from date of sale until redemption.

Redemption of property sold for delinquent assessments; effect on dissolution; deed; misnomer.

SEC. 47. Redemption may be made by owner or any party in interest within five years, or at any time thereafter before deed has been delivered. County recorder must file certificates of sale. If property not redeemed collector must, on demand, issue deed, subject to fee of two dollars.

SEC. 47½. Redemption period shall not bar dissolution of a district, and in any district that has been dissolved or is in process of dissolution, if land has been sold for delinquent taxes and redemption period has not expired, owner or any one in interest may redeem it. After dissolution, deed to unredeemed property shall be issued by county treasurer.

SEC. 48. Prescribes form of deed. When duly acknowledged or proved deed is, except against fraud, conclusive evidence of regularity of previous proceedings, and deed conveys absolute title, except that it is *prima facie* evidence of right of possession in case of lands owned by United States or state.

SEC. 49. Assessment book or delinquent list or copy thereof certified by collector, is *prima facie* evidence of facts and compliance with law.

SEC. 50. When land is sold for assessments correctly imposed, no misnomer or mistake relating to ownership affects sale.

SEC. 51. Collector to settle with secretary and treasurer on first Monday of each month, and within six days deliver to secretary statement under oath as to transactions.

PAYMENT OF BONDS AND INTEREST.

SEC. 52. Interest coupons paid from bond fund and whenever bond fund exceeds ten thousand dollars over amount necessary to pay interest due, district may after advertisement purchase from lowest bidders bonds not yet due to amount of said sum; but no bonds to be redeemed above par. If no bonds offered for sale, excess in bond fund to be invested in government or state bonds.

CONSTRUCTION OF WORKS.

Letting contract; payment of claims and care of funds; progress reports to State Engineer.

SEC. 53. After adoption of plans, and advertisement for twenty days, directors shall let work to lowest responsible bidder or bidders, or may reject any or all bids and readvertise, or may construct work under their own superintendence. Contracts for material to be awarded to lowest responsible bidder. Successful bidder to give bond for twenty-five per cent of contract price.

SEC. 54. Claims to be paid only on warrants. Sums in construction fund in excess of $25,000.00 may be deposited with county treasurer, who shall report receipts and disbursements second Monday in each month. District treasurer to report first Monday in each month.

SEC. 54½. During construction of work paid for from bonds, secretary to forward to State Engineer within one week after each regular meeting of board copies of progress reports made on such work; shall also forward to State Engineer copy of annual financial statement required by section 14, together with general report on

condition of works and other relevant matters. State Engineer to make such recommendations and comments as he may deem proper; he may also make further examinations, call for further information, or make further reports.

Payment for property or works or rental; tolls and charges; crossings; rights of way; dedication of waters.

SEC. 55. Costs of property and works to be paid out of construction fund, except that amounts due in yearly installments under lease or contracts shall be paid from annual assessments or from tolls and charges. For defraying expenses of organization, care, operation, management and repair and improvement of works completed and in use, and above mentioned installments, directors may in lieu (in part or in whole) of assessments, fix rates of tolls and charges.

SEC. 56. Directors shall have power to construct works across any stream, street, railway, canal, etc.; and every company whose railroad shall be so crossed shall unite with the district in forming crossings, cost thereof to be determined by agreement, or as in taking of land. Rights of way granted over state lands, and all water rights within district belonging to state, given, dedicated, and set apart for uses of district.

DIRECTORS AND OFFICERS.

Salaries and mileage; interest in contracts and penalties.

SEC. 57. Directors to receive four dollars per day each, and ten cents per mile mileage, and necessary expenses when engaged in official business under order of board; except that in districts of over five hundred thousand acres, directors shall receive one hundred and fifty dollars per month each in lieu of per diem. Directors shall fix compensation of all officers; except that on petition of at least fifty or a majority of freeholders, directors shall submit schedule of salaries and fees at any general election. Above petition to be presented between twenty and forty days prior to election.

SEC. 58. No director or officer shall be interested in any contract, violation constituting misdemeanor and resulting in forfeiture of office and liability to fine or imprisonment, or both.

SPECIAL ASSESSMENTS.

Levy by special election; levy without election; emergency levies; ascertainment of rate.

SEC. 59. Directors may call special election on special assessment to be used for any of the purposes of the act, election to be held in conformity with section 30. Two-thirds vote necessary to carry. If carried shall be added to annual levy. Assessment not exceeding two per cent of value of assessable property may be levied in any one year without vote by four-fifths of directors, total amount not to exceed $75,000.00; *provided*, that if petitioned by voters equaling in number fifteen per cent of votes cast at last general election within thirty days, special election on such levy shall be necessary; *and provided*, that in case flow in canal unexpectedly interrupted, four-fifths of the directors may levy assessments in any one year, at time of annual levy, not exceeding forty thousand dollars for repair of works, without election.

SEC. 60. Rate of assessments levied under act to be ascertained by deducting fifteen per cent for delinquencies and dividing sum voted by remainder of aggregate assessed value. Special assessments shall be collected in same time and manner as other assessments.

INCURRING INDEBTEDNESS.

Limitation; indebtedness before first assessment and payment by warrants; interest on warrants. Special provisions for districts of over 500,000 acres.

SEC. 61. Incurring of debt limited by express provisions of act, except that before collection of first assessment, directors may incur indebtedness up to two thousand dollars, or, if district contains more than four thousand acres, to one-half as many dollars as there are acres in district, and may issue warrants therefor, bearing interest at not more than seven per cent, and in no case exceeding fifty thousand dollars. Warrants to be payable not later than the first day of January after levying of first assessment.

SEC. 61*a*. Any warrant of district payable on demand, and presented for payment when no funds are available therefor, shall draw interest at not to exceed seven per cent, until public notice given that funds are available. After public notice interest on warrants shall cease.

SEC. 61*b*. Directors of districts of over 500,000 acres may acquire system supplying lands thereon, and where part of system lies outside of state, may exchange bonds for all or portion of system, or for interest in or stock of corporation owning all or part of system.

SEC. 61*c*. Where directors have exchanged or agreed to exchange bonds for property rights in system, as in section 61*b*, court shall decree validity of bonds issued or to be issued.

APPORTIONMENT OF WATER.

SEC. 62. General provision regarding water commissioners.

SEC. 63. Directors shall keep water in ditches to full capacity in times of high water.

SEC. 64. Navigation and mining not to be impaired or affected by act, except that rights of way may be acquired over property used in mining.

SEC. 65. General provision disclaiming authorization of any diversion except with previous compensation in accordance with the law.

EXEMPTION FROM TAXATION.

SEC. 66. Rights of way, ditches, reservoirs, etc., and other property of like character belonging to any irrigation district, not to be taxed for state, county, or municipal purposes.

FUNDS.

SEC. 67. Creates bond fund, construction fund, and general fund.

CONFIRMATION PROCEEDINGS.

Proceedings by directors; proceedings by assessment payer; consolidation of actions; disregard of error; contests.

SEC. 68. After issue of any bonds or levy of any assessment directors may bring action in superior court to determine validity. Action shall be in nature of proceeding *in rem* and jurisdiction of parties interested may be had by publication of summons. Validity may be contested by any party interested within ten days, with right of appeal to supreme court within thirty days, which must be determined within three months.

SEC. 69. If no proceedings brought by directors, any assessment payer may bring such action within thirty days after assessment or bond issue, directors being made defendant.

SEC. 70. Similar contests shall be consolidated.

SEC. 71. Court must disregard any error, irregularity, or omission which does not affect substantial rights of parties to action.

SEC. 72. Contests shall only be made within time and in manner specified in act, and in any such action, all findings of fact or conclusions of directors, or of supervisors, shall be conclusive, unless such action was instituted within six months after such finding or conclusion was made.

VIOLATION OF DUTY AND PENALTY.

SEC. 73. Violation of any express duty on part of any officer named in act shall render such officer liable on his official bond, and to removal from office by proceedings in superior court brought by any assessment payer.

EXCLUSION OF LANDS.

Covered by sections 74 to 84, inclusive. Land may be excluded in discretion of directors on petition of owner; *provided*, that upon petition it shall be duty of directors to exclude lands which are not susceptible to irrigation from a common source or by the same system of works with other lands of district, or from source or system chosen or adopted, or which are already irrigated, or entitled to be irrigated, from another source or by other works; except that no land irrigated by means of water pumped from an underground source shall be entitled to exclusion on account of being so irrigated if such land is or will be substantially benefited by subirrigation from works of district or by drainage works provided by district, but no owner of land so irrigated when district was organized and which has been so irrigated continuously each year exclusively by such means, shall be liable to assessment, except for interest and principal on district bonds. Holders of outstanding bonds are protected, by retaining lien against excluded lands for both bonds and interest, except where written assent of such bondholders to exclusion has been filed with district.

INCLUSION OF LANDS.

Covered by sections 85 to 97, inclusive. Owners of one-half or more of any contiguous tract adjacent to a district may petition for inclusion in said district. Directors may deny petition after hearing or may grant petition if no objection is offered by any person interested in district or proposed change, or if objections offered are withdrawn. If objections to inclusion are made and not withdrawn and directors still believe it for best interests of district that lands be included, matter shall be determined by majority vote at special election in district. Directors may require, as condition precedent to inclusion, that petitioners shall pay such sums as they would have been required to pay had such lands been included at the time of organization. Adjacent public lands of United States may be included without petition. If directors find unconditional inclusion would injure land already in district by impairment of water right, or greater expense of water for additional lands, they may prescribe conditions for inclusion, by providing for priority of water right or additional annual payment or other just conditions.

REDUCTION OF BONDED INDEBTEDNESS.

Covered by sections 98 to 99½, inclusive. Where no bonds are outstanding, authorized bonded indebtedness may be reduced if carried by majority vote at special election called by directors. If there be bonds outstanding, bonded indebtedness may be reduced with the assent of outstanding bondholders. Reduction of bonded indebtedness shall in no manner affect any order of the court confirming validity of bonds.

LEASE OF WATER FOR MECHANICAL PURPOSES.

Covered by sections 100 to 105, inclusive. If no increased expenditure is involved, directors may lease water owned by it for mechanical purposes, not inconsistent with the provisions of the act. Notice of intended lease must be published for twenty days, sealed proposals received, and lease let to highest responsible bidder, or bids

may be rejected. Rental on such lease shall be payable on thirtieth of December and thirtieth of June of each year. Lease may extend not exceeding twenty-five years. If rental not paid as due, amount may be doubled, and if not paid within ninety days thereafter, lease shall be forfeited to district, together with the works owned or controlled by lessee. Board may require lessee to execute bond or give other evidence of good faith.

DESTRUCTION OF UNSOLD BONDS.

Covered by sections 106 to 108, inclusive. Bonds remaining unsold after completion of system and payment of all demands may be destroyed on approval by two-thirds vote at special or general election called by directors.

SAVING CLAUSES.

Sections 109 and 110. Make districts organized prior to act subject to its provisions, so far as applicable, repeals original district act of 1887, etc.

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STATE OF CALIFORNIA
DEPARTMENT OF ENGINEERING

APPENDIX C

Investigations of the Economical Duty of Water for Alfalfa in Sacramento Valley California

1910-1915

By FRANK ADAMS, RALPH D. ROBERTSON, SAMUEL H. BECKETT, WELLS A. HUTCHINS, and O. W. ISRAELSEN, Cooperative Irrigation Investigations in California.

(Based on data gathered under cooperative agreement between the Office of Public Roads and Rural Engineering of the United States Department of Agriculture, the California State Department of Engineering, and the University of California Agricultural Experiment Station and reprinted from the Fifth Biennial Report of the Department of Engineering.)

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INVESTIGATIONS OF THE ECONOMICAL DUTY OF WATER FOR ALFALFA IN SACRAMENTO VALLEY, CALIFORNIA, 1910-1915.

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Cooperative Irrigation Investigations in California.

INTRODUCTION.

As a part of the cooperative irrigation investigations in California conducted under agreement between the Office of Public Roads and Rural Engineering,[1] the State Department of Engineering of California, and the California Agricultural Experiment Station, a series of experiments was begun in 1910 at the University Farm, at Davis, California, which sought to determine the most economical duty of water for alfalfa in Sacramento Valley. At the end of the third year of these experiments it was decided to supplement them by investigations on a large number of representative alfalfa farms in Sacramento Valley, in order to test the applicability of the results obtained at Davis to the varying soil and rainfall conditions in other parts of the valley. These latter studies were carried through the seasons of 1913 and 1914 and were in turn supplemented during the season of 1915 by studies on a temporary experimental plat about five miles northeast of Willows. In the meantime the experiments begun at Davis in 1910 were continued through a six-year period, ending with the close of the season of 1915. It is the purpose of this report to present the results of the entire investigation.

Bearing of the Investigation.

It is now well recognized, regardless of the crop irrigated, that a proper knowledge of the duty of water is of importance to both irrigators and the public, and especially is this the case in newly developing irrigated sections such as Sacramento Valley. In this large area where dry grain farming has prevailed so long, and where field crops and live stock admittedly are the basis of the most suitable agriculture for the area as a whole, a proper understanding of the amount of irrigation water that should be applied to alfalfa is of prime necessity. The irrigator must have this information that he may make the necessary arrangement for an adequate water supply, that he may avoid injury of his soil through the application of too much water, and that he may adjust to his land the amount available to him, so as to obtain the largest possible returns per acre-foot of water applied. Further, he

[1] Prior to July 1, 1915, between the Office of Experiment Stations and the California agencies named.

must have an understanding of the underground movement of irrigation water after it is applied, that he may be sure, on the one hand, that excessive losses are not occurring through too deep percolation, and, on the other hand, that the irrigation water is penetrating the soil sufficiently deeply to give proper nourishment to the feeding roots of the plants. Especially must the farmer have information as to what becomes of the irrigation water after it leaves the surface where there is such a large percentage of "hard" soil as in Sacramento Valley—soil into which, in its present poor physical condition, it is extremely difficult to make irrigation water reach even 12 to 24 inches below the surface.

EXPERIMENTS AT THE UNIVERSITY FARM AT DAVIS.

During 1910 and 1911, a tract of 8.19 acres was utilized in the experiments at Davis, the land being in square and contour checks 0.20 to 1 acre in area and averaging 0.28 acre. The soil of these plats is classified by the Bureau of Soils and the University of California as Yolo loam.[1] From 1912 to 1915, inclusive, 3.48 acres were utilized, divided into 15 square checks, averaging 0.23 acre each. The schedule of irrigation followed during the first two years included, in addition to check plats receiving no irrigation, total applications of 12, 24, 36, and 48 inches in depth. This same schedule was continued throughout the series of experiments, except that beginning in 1912 additional checks were provided that received depths of 18 inches and 60 inches, respectively, per year. The checks that received depths of 12, 18, and 24 inches were subjected to single applications at the rate of six acre-inches per acre. With total depths of 30, 36, 48, and 60 inches, individual applications were of 7.5 inches, 9 inches, 12 inches, and 15 inches, respectively. In 1910, 1912, and 1913, following winters of low rainfall, the first irrigations of the season were given immediately after the first cutting, but in 1911, 1914, and 1915, after relatively wet winters, irrigation began after the second cutting. Water was applied to the plats at Davis from a pumping plant on the tract which delivers approximately 0.9 cubic foot per second, and throughout the series of experiments the practice was to irrigate just as soon as possible after removing the crop from the field. In most cases the water was distributed in slip-joint pipe because it was not possible otherwise to obtain even distribution with the small irrigation head available. In every case, yields were weighed at the time of removal from the fields.

In the time of cutting, raking, shocking, and hauling the hay, standard field practices always were observed. That is to say, the alfalfa usually was cut when one-tenth to one-third was in bloom and the hay

[1] United States Department of Agriculture, Bureau of Soils, Reconnoissance Soil Survey of the Sacramento Valley, California.

generally was raked the same day, shocked the following day, and hauled as soon as it was dry enough to be stacked without heating, never being left until the leaves were dry enough to fall off when handled. The curing and removal of the hay from the field required from five to seven days. As soon as possible after the crop had been hauled from the field, irrigation water was applied.

The following table summarizes the results of the duty of water studies over the six-year period:

TABLE No. 1.

Summary of Alfalfa Duty of Water Investigations at Davis, 1910-1915.

Number of irrigations	Unit depth each irrigation, inches.	Depth of water applied, inches.	Yield, tons per acre							Average value of hay per acre at $7 per ton[1]	Average cost of production per acre[2]	Average profit per acre
			1910	1911	1912	1913	1914	1915	Average			
None	------	------	3.85	5.94	5.52	2.75	2.89	2.35	3.88	$27 16	$8 73	$18 43
Two	6	12	4.78	7.52	6.51	4.31	5.83	4.84	5.63	39 41	15 37	24 04
Three	6	18	------	------	7.02	5.69	8.02	6.46	6.80	47 60	19 35	28 25
Four	6	24	6.00	8.38	8.32	6.89	9.96	7.96	7.92	55 44	23 22	32 22
Four	7½	30	7.53	9.54	9.43	7.97	11.06	8.32	8.98	62 86	26 45	36 41
Four	9	36	7.58	9.35	9.38	8.22	12.48	8.63	9.27	64 89	27 96	36 93
Four	12	48	8.45	9.52	8.63	8.83	10.62	8.05	9.02	63 14	29 10	34 04
Four	15	60	------	------	10.17	7.25	10.70	5.55	8.42	58 94	29 44	29 50

[1]Market value of hay, 1910, 1911 and 1912, $11 per ton; 1913, $9; 1914, $4; 1915, $8.
[2]Labor of production, including cutting, raking, shocking and hauling, figured at $2.25 per ton. Water figured at $1.70 per acre-foot. Labor for irrigation figured at $0.50 per acre per irrigation.

Examination of this summary indicates that while both the average maximum yields and the average maximum profits were greatest in the case of annual applications of 36 acre-inches of irrigation water per acre, it is clear that neither the average increase in yield nor the average increase in profits, with applications at the rate of 36 acre-inches per acre per year over the average yields and profits with applications at the rate of 30 acre-inches per acre per year, was large enough to be material with water costing at the rate figured in the Davis experiments. It is plain, however, that to the extent that water costs less than $1.70 per acre-foot, the increase in net profits with annual depth of 36 inches over the figures for annual depths of 30 inches would be correspondingly greater, and very much greater if water were paid for at the flat annual rate of $1.50 or $2.00 per acre, as was the rule in a number of the Sacramento Valley areas included in the general investigation. The significant fact about the results at Davis is that the increase in yield tends to become negligible above annual depths of 30 to 36 inches, indicating that under conditions at Davis, a maximum allowance of 36 acre-inches per acre per year is ample. This is further brought out graphically in the accompanying chart. (Fig. 1.)

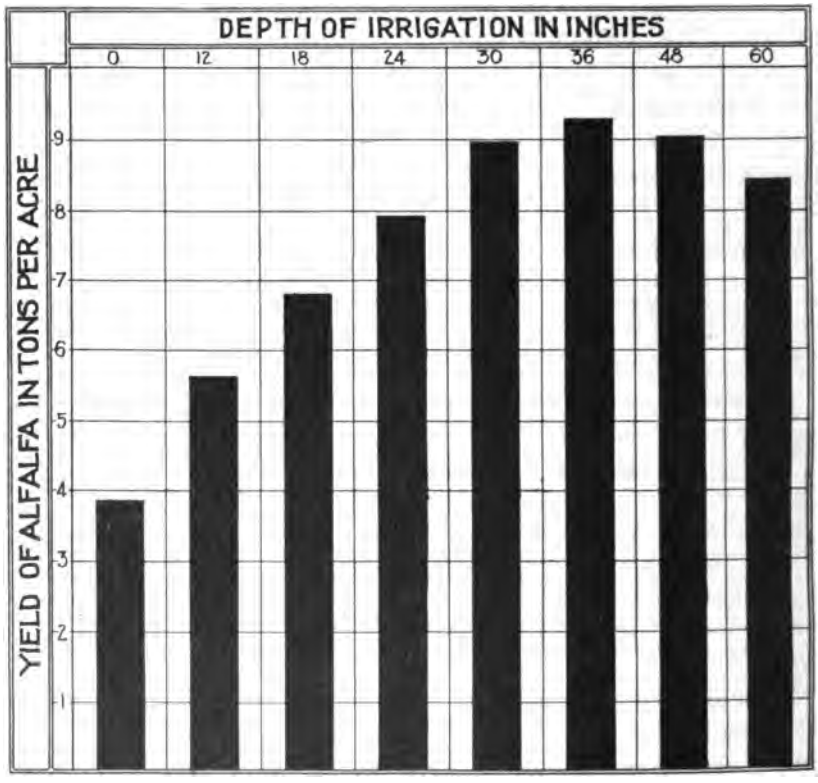


Fig. 1.—Diagram showing results of alfalfa duty of water experiments at University Farm, Davis, 1910 to 1915.

The most marked change from year to year in the relation of the averages to each other took place in the 60-inch applications. The 1912 yield from the most heavily irrigated plat was more than 10 tons per acre, but the average dropped to 8.42 tons per acre by 1915, and had the investigations been conducted longer this average doubtless would have decreased each year. The 1915 yield was only 5.55 tons per acre, owing to the quantity of rank water grass which had supplanted the alfalfa.

A wide variation in the seasonal rainfall and in the length of the growing season was observed at Davis. Both of these factors seemed

to have a decided effect on the yields of hay, as shown by the following table:

TABLE No. 2.

Relation of Climate to Yields of Hay at Davis.

Season	Rainfall	Length of growing season[1]		Average temperature, deg. F.	Number of cuttings	Average yield of hay per acre from all checks
		Dates	Number of days			
1909-1910	11.90	Mar. 22-Oct. 10	202	57.7	6	6.36
1910-1911	23.18	Feb. 27-Oct. 7	222	58.3	6	8.37
1911-1912	9.46	Mar. 3-Oct. 10	221	57.9	6	8.12
1912-1913	8.74	Mar. 4-Sept. 17	197	58.0	5	6.49
1913-1914	28.70	Feb. 6-Oct. 26	262	60.0	6	8.94
1914-1915	20.05	Jan. 23-Oct. 13	263	59.5	6	6.52
Average	17.00	Feb. 23-Oct. 9	228	58.6		7.48

[1]Period between date of last killing frost in the spring and the date of cutting last crop the following fall.

Although no conclusions are drawn from these observations the effect of climatological factors on crop growth and yields under irrigation is shown clearly.

Immediately following the harvesting of the last crop at Davis, on October 13, 1915, five areas, each containing 100 square feet, were laid off on each plat included in the experiment and the number of plants in each area counted. The probable number of plants per acre was figured from the average of these counts. By field count a good stand of mature alfalfa was found to contain an average of one and one-half plants per square foot. With this as a basis of comparison, the following table was compiled:

TABLE No. 3.

Estimated Per Cent of Alfalfa Stand Remaining at Davis at End of Six-year Experimental Period.

Number of plats	Depth of water applied, inches	Number of plants per acre	Per cent of good stand remaining
17, 30		8,625	13.2
12, 29	12	22,216	34.0
19, 28	18	30,928	47.3
20, 27	24	33,977	52.0
21, 26	30	41,382	63.3
22, 25	36	39,422	60.3
23, 24	48	38,333	58.7
31	60	17,598	26.9

This shows the effects of the two extremes in the application of water, especially when it is remembered that the observations on the 60-inch application extended over a period of only four years and in this time the stand, as a result of over-irrigation, was reduced to an estimated average of only 27 per cent of the original.

Soil Moisture Determinations at Davis.

Beginning with 1913 and extending through three years, very complete studies were made of the moisture content of the alfalfa plats. In the table below are given averages of the results of the three seasons observations, representing the number of inches applied and percentages retained by the upper six feet and upper twelve feet of soil. The plats which received no irrigation are not included in this table.

TABLE No. 4.

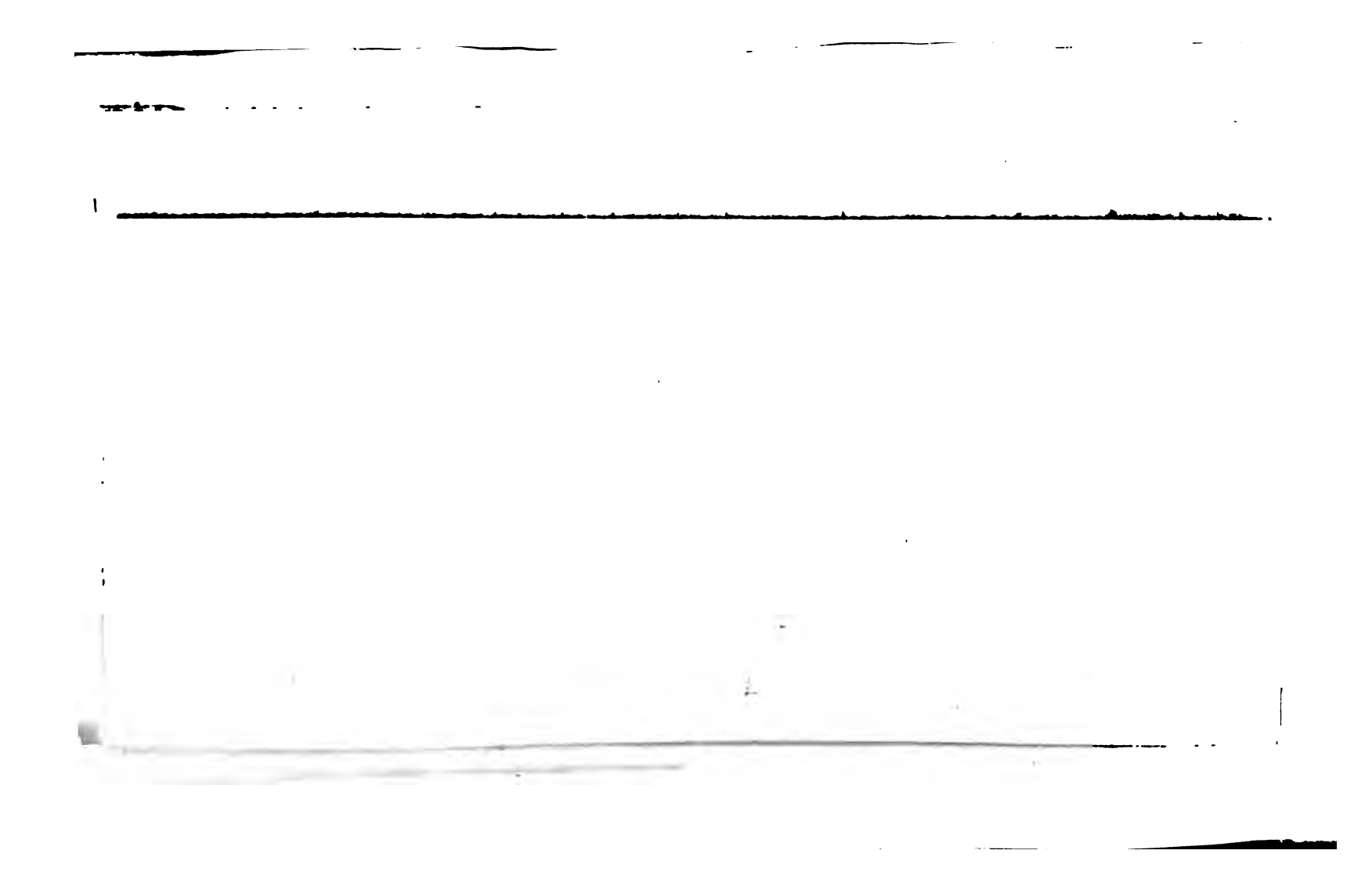
Acre-inches and Per Cent of Applications Retained by Soil, Davis Alfalfa Plats, 1913-1915.

Number of plats	Number of irrigations per season	Depth of water applied at each irrigation, inches	Amount of water retained in upper 6 feet of soil		Amount of water retained in upper 12 feet of soil	
			Inches	Per cent of quantity applied	Inches	Per cent of quantity applied
18, 29	2	6.0	3.81	63.5		
19, 28	3	6.0	5.52	92.0		
20, 27	4	6.0	4.43	73.8		
21, 26	4	7.5	5.10	68.0	8.00	106.6
22, 25	4	9.0	5.49	61.0	9.56	106.1
23, 24	4	12.0	6.68	55.6	10.32	86.0
31	4	15.0	9.24	61.6	13.09	87.2
Average, 6-foot tests[1]		6.0	4.59	76.4		
Average, 12-foot tests		9.5	5.76	[2]60.6	9.29	[2]97.7

[1]Plat 31 omitted from average.

[2]Group averages obtained by giving plat percentages weights proportional to quantities of water applied.

With the exception of plats 18 and 29 and 31, the percentage of water accounted for in the upper six feet of soil decreases with the increase in amount of water applied from 92 per cent for the plats that received three six-inch irrigations to 55.6 per cent for those that received four 12-inch irrigations. The total amounts of water retained in the same depth of soil per season increased with the increase of irrigation water. Examination of quantities retained by the upper 12 feet in plats 21 and 26 and 22 and 25 shows that more water was found in these plats than was applied. It is probable that this condition resulted from a lateral movement from plats 23 and 24 at a depth of seven to nine feet, or immediately above the relatively impermeable clay subsoil found at the ninth foot. This view is supported by the fact that plats 23 and 24 retained only 86 per cent of the twelve inches applied, while the average amount held by plats 21 and 26, 22 and 25, and 23 and 24, in the upper twelve feet of soil, was a little less than 100 per cent. Plat 31, having a finer textured soil, retained more than any other plat and a higher percentage than plats 23 and 24, which received less water.



In 1915, observations were made of the rate of growth of the alfalfa on the various plats. Owing to the fact that the varied irrigation treatments during the three preceding years had resulted in thinning out the stand on some of the plats, the actual rates of growth in 1915 resulted, in a measure, from the effect of these previous treatments. In order to eliminate the effect of thinness of stand and to make the 1915 rates of growth comparable from the standpoint of moisture alone, the growth rate on plats 21 and 26 is taken at 100 for each crop grown and the relative rates on the other plats computed on this basis. Plats 21 and 26 are taken at 100 because thirty inches of irrigation water per annum, the amount given to these plats, evidently represents the most economical duty for alfalfa under the conditions of these experiments. The actual growth rate of the six crops of alfalfa on the plats in 1915 was 49, 51, 112, 96, 106, and 45 pounds per acre per day, respectively. The relative rates of growth for all the plats are given in the following table:

TABLE No. 5.

Relative Rate of Growth of Each Crop of Alfalfa at Davis Experimental Plat, 1915.

Number of plats	Depth of water applied, inches	Relative rate of growth of each crop					
		First	Second	Third	Fourth	Fifth	Sixth
17, 30		47	58	22	22	17	9
18, 29	12	71	61	69	78	89	18
19, 28	18	84	88	78	76	89	45
20, 27	24	104	110	88	92	98	76
21, 26	30	100	100	100	100	100	100
22, 25	36	102	112	117	101	94	100
23, 24	48	104	98	96	110	96	98
31	60	94	86	48	66	42	49

That the preceding winter's rains thoroughly wetted the soil of the experimental tract throughout its entire depth is concluded from the soil moisture observations. Hence conditions in plats 17 and 30 and 21 and 26 for the period of growth of the first and second crops, other than variation in alfalfa stand, may be considered the same, for no irrigation water was applied to any of the plats before the second cutting. The relative rate of alfalfa growth for the first two crops on plats 17 and 30 averaged 50. Hence it appears that the last four cuttings produced 44, 44, 34, and 18 per cent, respectively, of what should have been produced had an average moisture percentage about six per cent above the point at which plants wilt, been maintained, as in plats 21 and 26. Instead, however, the moisture content during the growth period of the last three crops was about seven per cent below the wilting point in the surface foot, slightly below in the second foot, and approximately coincident with it in the lower foot sections.

This amount of moisture is insufficient to support a normal rate of growth. In plats 18 and 29, likewise, the moisture content in the surface foot fell below the wilting percentage shortly after the fourth cutting, and the fifth and sixth crops grew at the rates of only 56 and 26 per cent, respectively, of normal. In plats 19 and 28 the moisture content of the upper two feet was below the wilting point during the growth of the sixth crop, which was unirrigated, and resulted in a rate of growth of only 55 per cent of normal. Plats 20 and 27 showed a moisture percentage in the surface foot coincident with the wilting percentage before irrigation, but seldom approaching that point in the lower depths.

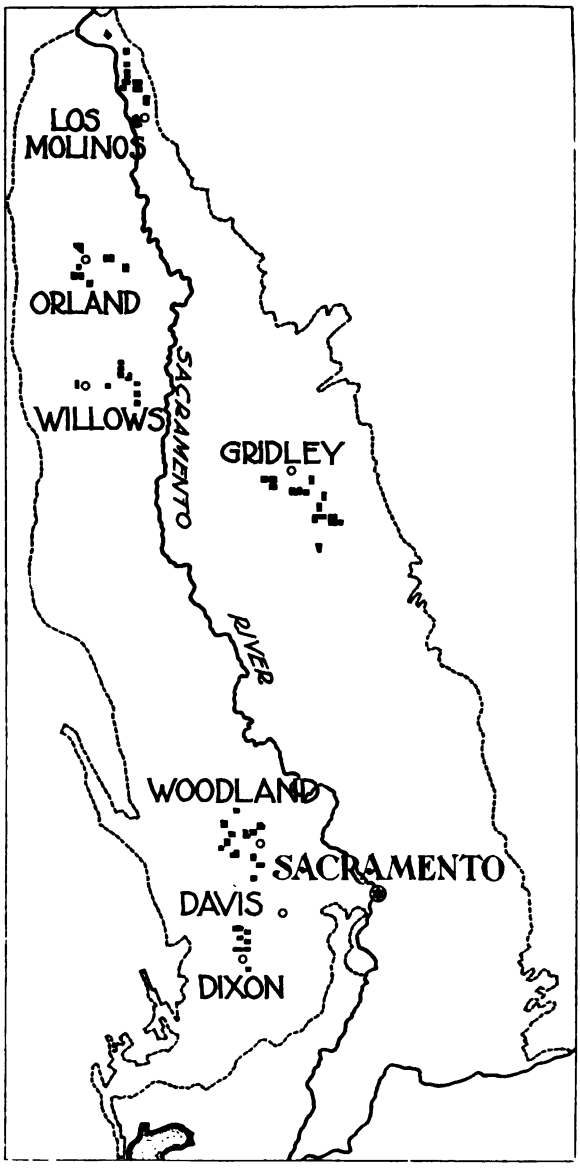


Fig. 2.—Outline map of Sacramento Valley showing location of alfalfa farms on which alfalfa duty of water measurements were made 1913 to 1915.

In plats 21 and 26, 22 and 25, and 23 and 24, very little change took place in the relative growth rates during the season, or in *average* moisture percentages. In plat 31, however, an increase in moisture percentage took place as the season advanced, and the small relative yields after irrigation began, that is of the last four cuttings, are due to an excess of moisture. Considering the average of the first two cuttings, as normal,

the third, fourth, fifth and sixth crops were respectively 53, 73, 47, and 54 per cent of normal, or an average of 56 per cent for the period of the irrigation season. On the same basis, plats 21 and 26, 22 and 25, and 23 and 24 produced respectively 100, 97, and 98 per cent of normal yields.

INVESTIGATIONS ON SACRAMENTO VALLEY ALFALFA FARMS.

In selecting the areas away from Davis to be included in the wider investigation (Fig. 2), care was taken to include enough fields so that there would be represented the major soil types of the valley as determined by the soil surveys of the bureau of soils and of the college of agriculture of the University of California, whose soil classifications have been followed in this report; also, to give the investigations as wide a geographical distribution as possible, so that the differences in rainfall could be taken into consideration. Accordingly, during the irrigation seasons of 1913 and 1914, between 40 and 50 representative farms were under observation in the neighborhood of Gridley, Los Molinos, Orland, Willows, Woodland, and Dixon, this work being supplemented in 1915 by detailed studies on a single ten-acre tract five miles northeast of Willows, and by general observations and measurements on four other farms.

While the experiments at Davis were conducted under normal field conditions, without departure from what may be termed merely good field practice, in the investigations on Sacramento Valley alfalfa farms, it was impossible, except in one case, to vary the quantities of irrigation water applied. Nevertheless, it was believed that by taking careful account of the irrigation water in the soil immediately before and shortly after irrigation, and by careful measurement of the amounts of water applied and of the crops taken off, it would be possible to obtain a satisfactory basis for correlation of results. Thus the investigation became not merely a measurement and study of the amounts of water used, but more particularly a study of the underground distribution of the irrigation water applied, and a critical inquiry into the capacity of the various soils of Sacramento Valley to retain irrigation water, the amounts or percentages of moisture necessary to maintain alfalfa growth, and the best means of maintaining these amounts under the conditions met.

Procedure.

Wherever possible, standard weirs were installed for measuring the water applied to the fields. Where sufficient fall was not available for this, and also where registers were not used, those conducting the field investigations made a sufficient number of current meter gagings or gage readings to give satisfactory evidence of the amounts of water being used. In a few instances, chiefly at Orland, automatic water registers were installed for obtaining continuous records. While all

the fields under observation were watched carefully for waste at the lower ends of the checks, no measurable waste was found. There was no waste of consequence off the fields where the largest quantities were used, such waste as did occur coming on the fields having heavy soils that failed to absorb the water.

In addition to measuring the quantities of water applied to the surface of the fields, the underground distribution of the water, following its application, was traced in as many cases as possible through soil sampling and moisture determinations. In taking soil samples, extreme care always was exercised to avoid holes previously bored. It was found impossible to trace the underground distribution of the irrigation water in all of the fields, but some work of this nature was done in each section studied. Borings were made to a depth of at least six feet and at least three points in each field one or two days before each irrigation and again at approximately the same points from two to five days after each irrigation. While this method left an interval of several days between soil sampling during which some moisture was used by the crops, and while it also failed to take account of the evaporation losses immediately following irrigations, substantially the correct relation was found by extending the moisture percentage curves, shown in the diagrams accompanying the text, so as to coincide with the moisture percentages immediately before and after increases due to the irrigations. In taking the soil samples for moisture determinations, small tins with an approximate capacity of one-half pound, and with tight-fitting covers, were filled from the center of each foot section; that is, at one-foot intervals beginning one-half foot below the surface and extending to five and one-half feet. During 1913 these samples usually were dried in electric ovens at local field headquarters, but in 1914 all were forwarded to the laboratory at Davis where they could be handled more conveniently. The tins were shipped in tight-fitting compartments in specially made boxes holding 18, a sufficient number of check determinations having been made in the field and in the laboratory to insure that moisture loss in transit would be negligible.[1]

In measuring the areas of the alfalfa fields under investigation, all principal supply ditches were eliminated, but the areas reported include borders and levees and small field distributing laterals which carried the water from the main supply ditches to the checks.

A number of considerations were held in view in making the soil moisture determinations connected with these investigations. In the first place it was desired to ascertain the depth of percolation of the

[1]Weighing of about 700 samples both in the field and in the Davis laboratory showed an average loss slightly less than 0.1 per cent during an average time of 36 hours.

irrigation water in order to know in a general way whether it was getting into the soil sufficiently to meet the needs of the crop, and also whether any appreciable amount was passing below the zone of greatest root growth, generally taken to lie within the upper six feet of soil. In order to express this underground distribution of the irrigation water in a way that would be generally intelligible, the moisture content of each of the upper six feet of soil was first determined in inches per foot of depth of soil and the amounts of water added by irrigation then were determined; also, in inches per foot in depth of soil, on the basis of the borings before and after irrigations. Thus, with the water content of the upper six feet of soil before irrigation known (in some cases the upper 9 or 12 feet), and with an accurate measurement of the amount of water applied to the fields, it was possible to estimate quite closely the proportion of the water that remained or was utilized immediately and the proportion that passed below the depths studied.

Another consideration in view in these determinations was to ascertain the relative amounts of irrigation water contained in the upper six feet of soil as compared with the quantities necessary to prevent wilting of the plants.[1] It was reasoned that this information would indicate, with considerable accuracy, the quantities of water necessary to apply to the several types of soil to meet adequately the needs of the crop.

A final consideration, in view in these studies of the underground distribution of the irrigation water, was the frequency with which irrigation water should be applied in order to meet fully the needs of the plants. In other words, it was desired to learn to the extent possible in the investigation the relative advantages of single irrigations between cuttings and of the more frequent irrigations given to alfalfa in some sections and on some soils. It is plain, for instance, that the less retentive a soil, the greater the frequency of applying irrigation water; also, that the "tighter" the soil, the greater the difficulty of getting into it at one time the amounts of water needed to mature a cutting. This last consideration was especially prominent in connection with the gravelly soils near Orland and the very heavy soils found in some of the sections about Willows. In fact, it was the difficulty of getting irrigation water into heavy soils that led to the continuation

[1] Expressed technically, the quantities of irrigation water in the soil over and above the "wilting coefficient." For a discussion of this term and its application see United States Department of Agriculture, Bureau of Plant Industry Bulletin 230. In this report the simpler terms, "wilting point" or "wilting percentage" are used.

of the investigations during 1915 on a single typical field northeast of Willows.[1]

In the course of the three years of investigation approximately 11,000 moisture determinations have been made, not including those made for the plats at Davis. Of these, 8,000 determinations were for moisture-holding capacity. The soil samples used in these determinations were taken with two-inch soil augers of the posthole type. The field and laboratory records were made on special forms devised for the investigation, and in the soil moisture determinations at Davis a special electric oven was used, the soil being heated to a temperature of 105° to 115° centigrade.

In every case where the amount of water used was measured, the crop yields were ascertained by the most satisfactory means available. In some cases crops either were sold in bulk according to scale weights, or baled, making exact weights available. In a few cases stacks were measured or a sufficient number of shocks to be representative of the whole were hauled to nearby scales and the average weight per shock obtained. In a large number of cases the average weight of shocks was ascertained by weighing on the ground by means of special apparatus devised for the purpose. (Plate I, Fig. 1.)

Gridley Area.

Investigations were conducted here in 1913, only, the work being discontinued after that year because of the high water-table and the consequent impracticability of tracing the underground distribution of the irrigation water applied. Work was done on 14 tracts varying from three acres to 67 acres in size. (Fig. 3.) All of the fields studied received water from the Sutter-Butte canal, which takes its supply from Feather River. The charge for water for alfalfa is $2 per acre per year except to some early settlers who pay $1.

The building of the Sutter-Butte canal system and the introduction of irrigation into this area in 1905 was not accomplished without difficulty. Like other sections of Sacramento Valley, the area was devoted to dry grain farming, although fruit was grown in some sections, also without irrigation. In less than ten years the most skeptical of the old-time grain farmers have become convinced that irrigation is profitable and essential in the up-building of the section. But irrigation has

[1] In ascertaining the capacities of the various soils under observation in the investigation to retain irrigation water and the rates of percolation of the irrigation water applied, it was necessary to make numerous technical studies which it is not desirable to report in this bulletin. The ascertainment of the water-holding capacities of the various soils and of the amounts of moisture necessary to be present to prevent wilting have, for instance, involved the making of apparent and real specific gravity determinations, physical analyses of the soil in the various fields, and the development and checking of special methods of volume-weight determinations of soils "in place." In some of these studies the cooperation was received of Professor Charles F. Shaw, and assistants, of the Division of Soil Technology of the Department of Agriculture of the University of California.

PLATE I.

Fig. 1.—Weighing alfalfa hay in the field.

Fig. 2.—Measuring the irrigation "head" with a current meter on Hofhenke alfalfa farm, Los Molinos.

brought problems relating to drainage and the conservative use of water, which are yet to be solved. The average annual rainfall at Biggs, four miles north of Gridley, is 22.24[1] inches.

The soils of the Gridley area have been classified by the bureau of soils and the University of California as Madera and Gridley loams, undifferentiated. Naturally, in a broad classification many departures are to be found. Southeast of Gridley there occurs a body of silt loam within which were located a number of the tracts included in the investigations in 1913. Under most of the soils a noncontinuous hardpan is found within six feet of the surface and occurs frequently within 18 inches, or again may be absent entirely. To quote from the report of the reconnoissance soil survey by the bureau of soils and the University of California.[2]

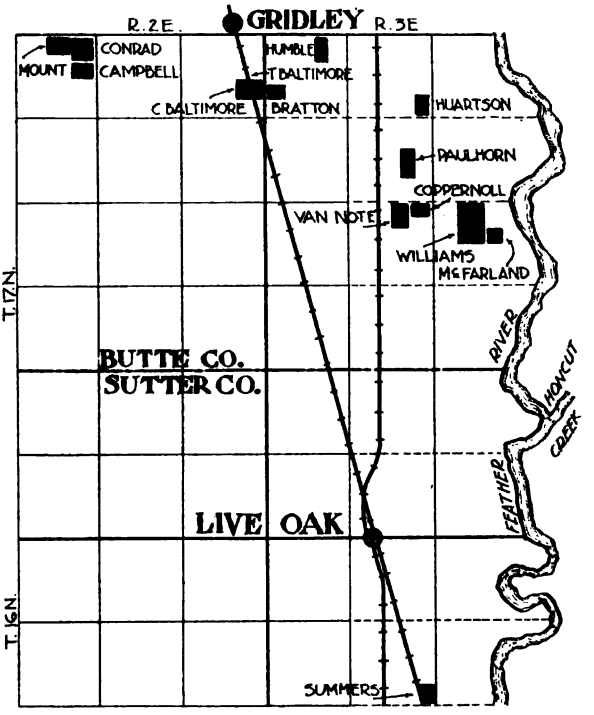


Fig. 3. Map of Gridley area showing location of alfalfa farms under investigation, 1913.

It will be noted in the description of the individual tracts mentioned later that ground water was found in many fields within three feet to five feet of the surface. As far back as 1907 it stood within six feet of the surface under large areas and after a few days of irrigation rose, in many cases, to within three feet of the surface. In general, the water-table seems to fluctuate over wide ranges and to vary considerably within each season. The need for drainage is well recognized and in some sections it has been or is being provided.

[1] Weather Bureau, Annual Summary for 1915.

[2] U. S. Dept. Agr., Bureau of Soils, Reconnoissance Soil Survey of the Sacramento Valley, California, p. 87. The hardpan layer in these soils is variable, being in places a thin stratum of easily fractured gray material, usually high in calcium carbonate. In other places it is a very thick, cemented mass lying near the surface. In still other places it is a semicemented mass of mottled grayish and reddish-brown color. The hardpan has a direct and important influence upon the crop value of the soils of this group. As a whole they are friable, easily tilled and retentive of moisture.

Most of the land planted to alfalfa in the Gridley section is prepared in border checks 30 feet to 60 feet wide and 300 feet to 1,000 feet long. Many of the early settlers used rectangular checks with from five to seven to the acre. In applying water to the border checks, which now predominate, an irrigating head of 10 to 15 cubic feet per second is commonly used, most generally divided between two or three checks. The cost of preparing land for irrigation of alfalfa has averaged from about $15 to $20 per acre. The first irrigation of alfalfa generally is given after the first crop of hay is removed, usually in May or early June. Subsequent waterings follow each cutting with the exception of the fifth or last.

As indicated in Table No. 6, the average use of water on the 14 farms under observation in 1913 was 3.31 acre-feet per acre for the season, and the average total yield from five cuttings of alfalfa was 6.19 tons per acre, this yield having been reduced as a result of an invasion of grasshoppers. The greatest quantity used was 4.98 acre-feet per acre applied in five irrigations, and the least was 2.04 acre-feet per acre applied in four irrigations. In several cases the extravagant use noted was due to the inexperience of the irrigator or to a lack of attention when water was being applied. The fact that water usually was sold to irrigators at a flat rate of $2 per acre and with little restraint exercised by the canal company, had a tendency to promote extravagant use. A change in the method of selling water from a flat rate per acre to the quantity basis is desirable, and would to some extent obviate the dangers of overirrigation.

The underground distribution of the irrigation water applied was traced on the Huartson and Williams fields in the Gridley area in 1913.

Huartson Field. The soil is a loam of the Madera and Gridley series, generally uniform to a depth of six feet, and highly permeable. A noncontinuous hardpan about six inches thick is encountered from four to six feet below the surface. Below this is a rather porous, coarse, sandy loam to a depth of about ten feet, with a very impervious, compact, blue clay underlying to a depth of 20 to 50 feet. This field was irrigated four times, moisture determinations being made before and after each of the last three irrigations. At the second irrigation a depth of 7.44 inches was applied, of which 1.68 acre-inches per acre, or 23 per cent, was retained in the upper six feet. A depth of 7.32 inches was given at the third irrigation, of which 5.97 acre-inches per acre, or 82 per cent, was retained in the upper six feet. A depth of 6.84 inches was given at the fourth irrigation, of which 4.88 acre-inches per acre, or 71 per cent, was retained in the upper six feet. In each case four

borings were made before and after irrigations, and ground water generally was found at a depth of approximately six feet, the latter obviously affecting the moisture content of the soil almost to the surface. Borings to a depth of six feet after the fourth irrigation indicated that almost all of the pore space in the sixth foot of soil was filled with water. Considering the last three irrigations together, it was found that 58.1 per cent of the quantity of water applied was retained in the upper six feet, this being increased to 73 per cent by adding an estimated quantity for loss between irrigations and soil borings. Throughout the period of the last three irrigations, the moisture content below the second foot in depth was far above the wilting point. Considering the high ground water level under this field it is obvious that even the 6.84 to 7.44 acre-inches per acre applied at single irrigations to this field were slightly excessive.

Williams Field. The soil is a little more compact and less permeable than that in the Huartson field. Five irrigations were given in 1913 and moisture determinations were made from four borings before and after the second, third, and fourth, the depths of water applied in these three irrigations being 6, 4.44, and 7.20 inches, respectively. In boring for soil samples it was attempted to go to a depth of six feet, but the high water-table prevented satisfactory results below a depth of three feet. The average quantity of water applied at the second, third and fourth irrigations was 5.88 acre-inches per acre, of which an average of 47 per cent was retained in the upper three feet of soil.

Results of these investigations are summarized in Table No. 6.

TABLE No. 6.

Summary of Results of Alfalfa Duty of Water Investigations, Gridley Area, 1913.

Name	Soil type	Area, acres	Number of irrigations	Total depth water applied, feet	Number of cuttings	Total yield, tons per acre
J. W. Humble	Silt loam	18.43	4	2.55	5	5.84
T. Baltimore	Silt loam	14.93	4	3.42	5	7.20
F. L. Bratton	Silt loam	3.29	4	3.82	5	6.88
Chas. Baltimore	Silt loam	26.40	5	4.98	5	6.96
W. R. Huartson	Silt loam	7.42	4	2.64	5	9.38
C. W. Van Note	Clay loam	27.20	5	2.37	5	5.97
W. G. Coppernoll	Silt loam	13.96	5	2.83	5	7.28
M. B. Williams	Silt loam, clay loam	67.29	4	2.04	5	5.80
A. J. McFarland	Silt loam	9.44	5	4.16	5	4.19
John Paulhorn	Silt loam	17.10	4	3.93	5	5.88
C. W. Summers	Sandy loam	7.00	4	2.23	5	5.92
G. W. Conrad	Silt loam, sandy loam	37.59	6	3.81	5	4.84
G. L. Campbell	Silt loam, sandy loam	16.76	5	3.89	5	6.13
C. W. Mount	Clay loam	17.41	6	3.70	5	4.54
Averages				3.31		6.19

NOTE.—Rainfall November 1, 1912, to October 31, 1913, 1.16 feet.

DESCRIPTION OF FIELDS IN THE GRIDLEY AREA AND COMMENTS ON IRRIGATION CONDITIONS AND PRACTICES.

J. W. Humble Field. Seeded in 1909. Stand of alfalfa uniform. Water table at 3.5 feet below surface during irrigation season. Field in border checks about 60 feet by 260 to 440 feet, with average grade of four inches in 100 feet. Levees four feet wide on top, 8 feet wide on bottom, and six inches high. Water applied once after each cutting, with the exception of the last. An irrigation head of 4.5 to 6.5 cubic feet per second, divided between two checks, irrigation progressing at rate of .8 to 1 acre per hour.

Thurston Baltimore Field. Seeded in 1911. Field prepared in border checks 35 feet wide and 870 feet long with average grade of eight inches per 100 feet in the upper one-half of the field and four inches per 100 feet from center to lower end. Water applied once after each cutting, with exception of last. Head of eight to ten cubic feet per second being divided between two or more checks, no water being wasted at lower end of checks. Borings were made in 1913 to depth of six feet before and after each irrigation. In the higher part of field water table stood five to six feet below surface, while in lower end it was two feet below, these depths being about constant throughout irrigation season.

F. L. Bratton Field. Seeded in 1908. Stand of alfalfa good. Land in rectangular checks averaging 45 feet by 72 feet. Average irrigation head varied from four to eight cubic feet per second, being divided into four or more checks. Four irrigations given. Use could have been greatly reduced by better location of field ditches and arrangement of checks. The fact that several different men were hired to irrigate also accounts for excessive use of water.

Chas. Baltimore Field. Seeded in 1907. Lies west of Thurston Baltimore tract and has good stand. Water table stood at about 3.5 feet below surface during irrigation season. One-half of field prepared in border checks 30 feet by 400 feet with average grade of five inches in 100 feet, remainder being in rectangular checks 70 by 80 feet. Average irrigation head 4.5 to 6 cubic feet per second, generally turned into two or more checks. Water applied after first and second and before third, fourth, and fifth cuttings. Better results might have been secured in part of field by increasing size of head used on individual checks.

W. R. Huartson Field. Seeded in 1909, has excellent stand. Field in border checks 65 feet by 600 feet with average grade of 2.5 inches in 100 feet. Head of 1.7 to 3.5 cubic feet per second applied once after each cutting except the fifth. Water table five to six feet below surface during irrigation season. Water carefully used and excellent returns secured.

C. W. Van Note Field. Seeded in 1909. Stand good and land well prepared for irrigation. Water table four to six feet below surface during irrigation season. Field in border checks, most of which are 50 feet by 620 feet with average grade of two to three inches in 100 feet. Irrigation head of 8 to 13 cubic feet per second divided among two or three checks, irrigation with latter head progressing at rate of about two acres per hour. Water applied once after each cutting and use conservative.

W. G. Coppernoll Field. Seeded in 1910. Stand good and land well prepared in border checks 50 to 55 feet by 460 to 560 feet, with average grade of five to six inches in 100 feet. Average head of 13 to 16 cubic feet per second divided among three or four checks, the land being irrigated at rate of about three acres per hour.

Milo B. Williams Field. Seeded in 1908. Stand good and preparation of land fair. Water table 3 to 3.5 feet below surface during irrigation season. Field in rectangular and border checks of various sizes, some 80 feet by 200 feet and others 60 feet by 450 feet. Average irrigation head varied from 10 to 16 cubic feet per second, divided into two or three streams. Two men usually irrigated at rate of two or three acres per hour and use was conservative.

A. J. McFarland Field. Seeded in 1909. Stand and preparation of land fair. Field divided into border checks 60 feet by 623 feet with average grade of eight

inches in 100 feet. Average heads of eight to ten cubic feet per second divided between two checks. Inexperience of irrigator and lack of attention during times of watering accounts largely for the extravagant use of water.

John Paulhorn Field. Seeded in 1908. Water table 3.5 feet below surface during irrigation season. Field irrigated by flooding from field ditches, 13 to 15 cubic feet per second being divided into two or three ditches. A more economical use of water could have been attained with better preparation of the land.

C. W. Summers Field. Seeded in 1907. Water table three to five feet below the surface during irrigation season. Field in border checks 55 feet by 465 feet, with average grade of four inches in 100 feet. Average irrigation head of four to six cubic feet per second applied once after each cutting of alfalfa, with exception of fifth, irrigation progressing at rate of one acre per hour.

G. W. Conrad Field. Seeded in 1909. Land well prepared and stand fair. Water table about 3.5 feet below surface during irrigation season. Field in border checks 40 feet by 600 feet, with average grade of 0.6 inch in 100 feet. Levees have bottom width of four to six feet and are six inches high. This tract received six irrigations with average of five to seven cubic feet per second.

G. L. Campbell Field. Seeded in 1911. This tract adjoins Conrad tract and has good stand. Water table 3.5 feet below surface during irrigation season. Field in border checks, some 35 feet by 280 feet, with average grade of four to six inches per 100 feet. Average of five to seven cubic feet per second turned into three or four checks. Sometimes irrigation practised at night and water allowed to waste.

C. W. Mount Field. Seeded in 1910. Land fairly well prepared for irrigation but stand has been damaged by excess of water. Water table about 3.5 feet below surface during irrigation season. Field in border checks 60 feet wide and varying in length from 420 to 1,160 feet, with average grade of two inches per 100 feet. Average of four to six cubic feet per second used and considerable water wasted through carelessness of hired irrigators.

Los Molinos Area.

Investigations were conducted on nine fields near Los Molinos in 1913 and on ten fields in 1914, all lying within the 12,000-acre Los Molinos irrigation project, in Tehama County. (Fig. 4.) The first development under the Los Molinos project was in 1908, and by 1914 about 8,500 acres were under irrigation and about 350 families were living on the project.

The average annual rainfall at Red Bluff, about 15 miles north of Los Molinos, is 26.11 inches.[1] Water for irrigation is obtained from Mill and Antelope creeks and is sold by the water company at the flat rate of $2 per acre with a contract allowance of one-fifth "miner's inch" per acre, a miner's inch being defined as 14,000 gallons in 24 hours.

The irrigation season for the project is fixed at April 1 to October 1, but due to an abundance of water and to the fact that the project is not yet completely under irrigation, the established rules governing the distribution of water have not been enforced. Water is delivered in rotation in heads of two to five cubic feet per second and the usual practice is to irrigate alfalfa once after each cutting with the exception of the fifth or last crop. The most common method of preparing land

[1]Weather Bureau, Annual Summary for 1915.

is in border checks 40 feet to 60 feet wide and 300 feet to 600 feet long, with a usual grade of three inches to six inches in 100 feet. A number of fields, however, have not been prepared for irrigation other than by some "floating" of the surface.

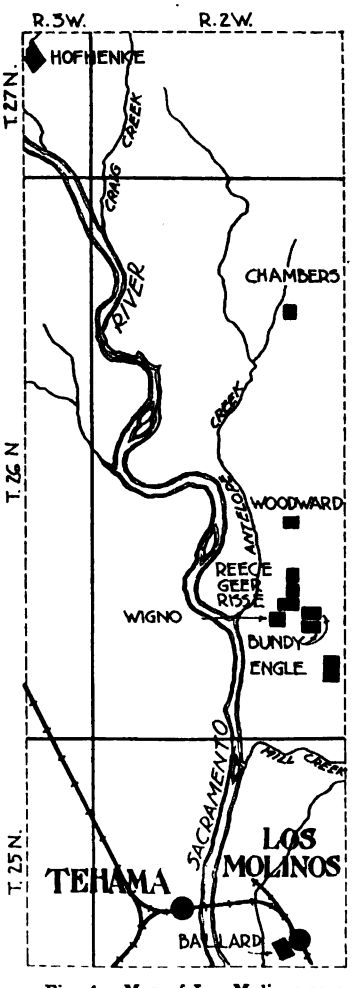


Fig. 4.—Map of Los Molinos area showing location of alfalfa farms under investigation, 1913 and 1914.

During the season of 1913 duty of water measurements under the Los Molinos project were made mostly with a current meter (Plate I, Fig. 2), but in 1914 most of the fields were equipped with rectangular or Cipolletti weirs installed at the entrance of the laterals to the farms. Soil moisture determinations in 1913 were confined to miscellaneous borings and determinations through a part of the season, but in 1914 these determinations were made with fair completeness on five fields. The soils in the Los Molinos area are designated by the bureau of soils[1] as belonging to the Vina series and include mostly clay loams and silt loams.

It is to be noted from the summaries in Tables Nos. 7 and 8 that the actual applications of water varied from 1.42 to 8.46 acre-feet per acre per year, averaging 5.57 acre-feet per acre in 1913 and 4.74 acre-feet per acre in 1914; also that a smaller average use in 1914 gave a larger average yield of alfalfa than was obtained in 1913, undoubtedly due largely to the fact that the rainfall in 1914 was over twice that of 1913. But even when rainfall is added to the irrigation water applied each year there are many instances shown in the summaries where larger quantities of water, both irrigation and rainfall, fail to give proportionate increases of yield. For instance, a total of 6.07 acre-feet of water per acre on the Bundy No. 1 farm gave a yield of 3.02 tons per acre in 1913, whereas a total of 5.08 acre-feet of water per acre on the same farm in 1914 gave a yield more than 90 per cent greater. Again, a total of 4.94 acre-feet of water per acre on the Hofhenke farm in 1913 produced a yield of 8.10 tons of alfalfa, whereas

[1] U. S. Dept. Agr., Bureau of Soils, Reconnoissance Soil Survey of Sacramento Valley, California.

a total of 9.74 acre-feet of water per acre, including rainfall, in 1914 gave a yield of only 5.75 tons, or 28 per cent less.

Soil moisture determinations were made on the Wigno, Bundy, Hofhenke, Geer, and Woodward fields in this area in 1914. The soils of all of these fields were highly permeable. Large quantities of water were applied in each case and the moisture determinations showed beyond a doubt that much water passed below a depth of six feet. In the fine sandy loam soils studied on the Wigno tract the increase in moisture content was as great in the sixth foot as in the surface foot. In the case of the other four fields the increase in the lower depths also was sufficient to indicate that much of the irrigation water passed below the depths reached by the soil augers. Speaking generally of the four fields, the moisture work indicated that as much water would have been held by the soils if less had been applied; also that sufficient moisture was in the soils of all four fields almost throughout the season to keep the percentage above the wilting point. A more complete statement of moisture work on these five fields follows.

Wigno Field. Figure 5 shows diagrammatically the changes of moisture content in this field throughout the irrigation season of 1914 for each foot in depth in the upper six feet of soil.[1] The soil of this field is fine sandy loam of the Vina series, and is very uniform to a depth of 12 feet. The field was irrigated four times in 1914. The first moisture samples were taken May 8th, eleven days before the first irrigation, the average moisture content shown by three borings to a depth of six feet having been 15.65 per cent. An irrigation on May 19 of 5.95 acre-inches per acre raised the moisture content in the upper six feet of soil to 25.71 per cent of the water applied; 90 per cent was retained in the upper six feet, the quantities retained in each foot increasing with the depth. The second irrigation, amounting to a depth of 23.18 inches, was given June 20th, eight borings for moisture samples being made June 18th and June 24th. Only 5.67 of the 23.18 acre-inches applied per acre, or a little less than 25 per cent of the total, was retained in the upper six feet of soil. The third irrigation, amounting to a depth of 15.78 inches, was given July 28, moisture samples being taken from eight holes July 22d and July 30th. A total of 4.90 acre-inches per acre, or approximately 31 per cent of the amount applied, was retained in the upper six feet of soil. The last irrigation, amounting to a depth of 28.04 inches, was given on September 10th, eight borings for moisture samples nine feet deep being made September 7th and again September 14th. A total of 4.83 acre-inches per acre, or 17 per cent of the amount applied, was retained in the upper nine feet, 12 per cent, or 3.48 acre-inches per acre, being retained in

[1]More correctly speaking, this and subsequent similar charts show the range of moisture change between irrigations and at each irrigation.

the upper six feet. On November 5th, after the last crop of alfalfa had been removed, eight borings to a depth of six feet showed an average moisture content of 16.53 per cent. Considering the four irrigations together, they are found to average a depth of 18.25 inches each, of which 4.89 acre-inches per acre, or an average of 26.8 per cent of the total was retained in the upper six feet. The diagram shows that the moisture percentage reached or closely approached the wilting point in the upper three feet of soil before each irrigation, but that it

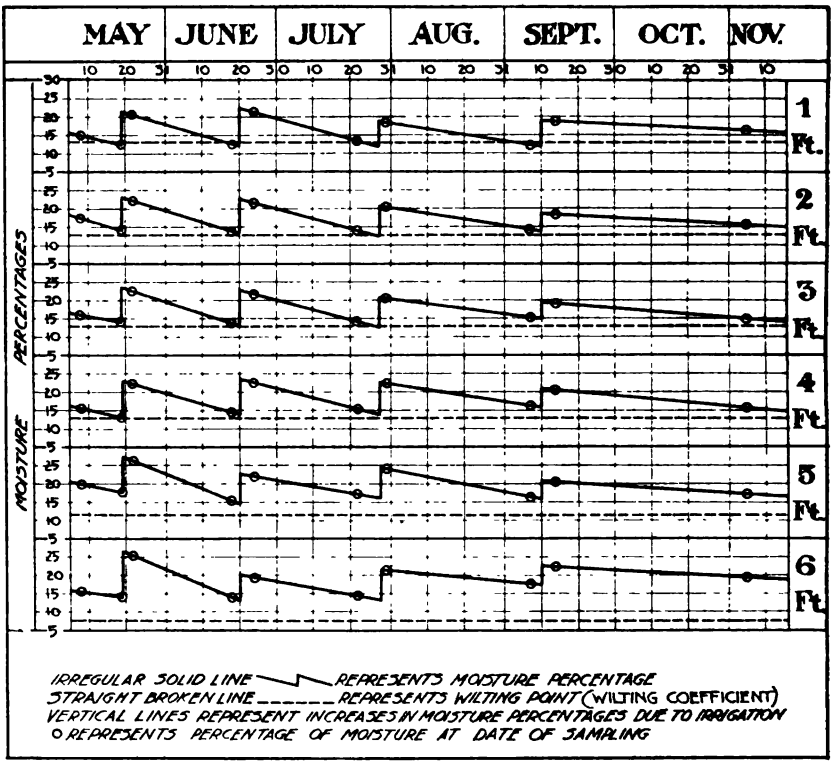


Fig. 5.--Diagram showing seasonal variation in soil moisture percentage, Wigno alfalfa field, Los Molinos, 1914.

was well above the wilting point throughout the season in the third, fourth, and fifth feet below the surface.

Bundy Field. Variations in moisture percentages in this field are shown in figure 6. The soil of this field is a loam of the Vina series, uniform to a depth of at least 12 feet. Four irrigations were given in 1914, 17.72, 12.20, 11.55, and 7.77 acre-inches per acre, respectively, being applied. Six borings were made to a depth of six feet before and after each of the first three irrigations and to a depth of nine feet before and after the fourth irrigation, the moisture determinations

indicating that 4.01 acre-inches per acre, or 23 per cent, was retained in the upper six feet at the first irrigation, 3.27 acre-inches per acre, or 27 per cent, at the second irrigation, 4.03 acre-inches per acre, or 35 per cent, at the third irrigation, and 4.73 acre-inches per acre, or 61 per cent, at the fourth irrigation. The average quantity of water applied in the four irrigations was 12.30 acre-inches per acre, of which an average of 4.03 acre-inches per acre, or 32.5 per cent of the amount applied, was retained in the upper six feet of soil. In this field, as shown by the diagram, the moisture percentage reached the wilting point only in the first foot.

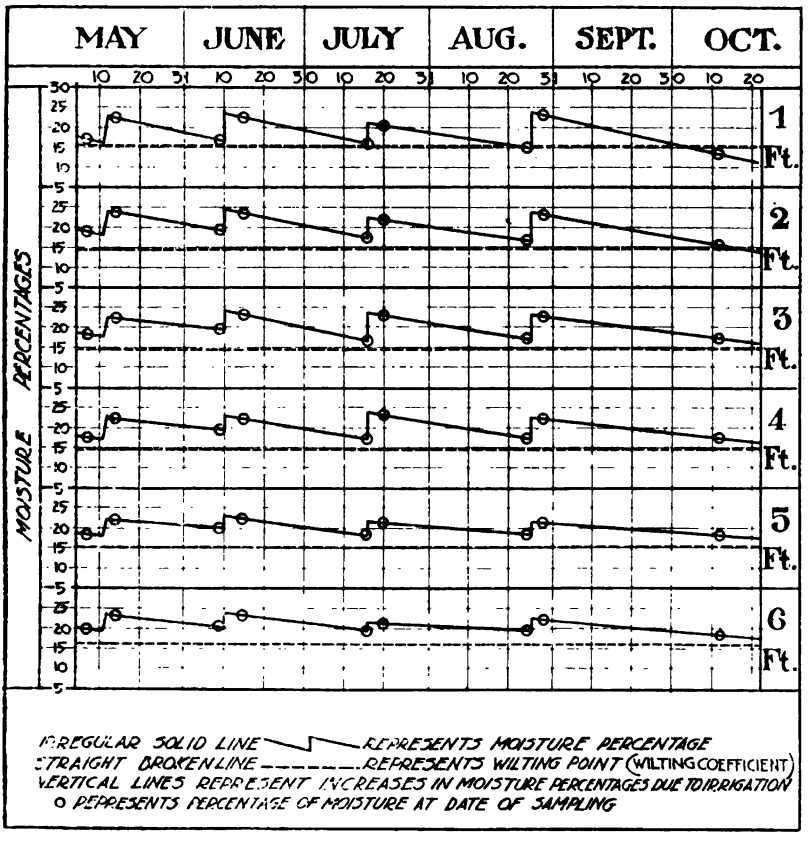


Fig. 6.—Diagram showing seasonal variation in soil moisture percentage, Bundy alfalfa field, Los Molinos, 1914.

Hofhenke Field. Variations in soil moisture percentages in this field are shown in figure 7. Only in August and in the surface foot of soil did the moisture percentage drop to the wilting point. The soil of this field is loam of the Vina series. Irrigations were given in 1914 on June 1st, July 11th, August 16th, and September 21st, the depths

of water applied being, respectively, 18.76, 15.74, 18.86, and 13.22 inches. Moisture determinations were made to a depth of six feet before and after the first three irrigations and to a depth of nine feet before and after the fourth, nine borings being made before and after the first irrigation, and 12 before and after each of the others. The quantities of water retained in the upper six feet of soil in the four irrigations were 5.42 acre-inches per acre, or 29 per cent, at the first irrigation, 3.78 acre-inches per acre, or 24 per cent, at the second irrigation, 5.36 acre-inches per acre, or 28 per cent, at the third irrigation, and 3.50 acre-inches per acre, or 26 per cent, at the fourth irrigation. At the latter irrigation 4.65 acre-inches per acre, or 35 per cent, was retained in the upper nine feet of soil. The average depth at each of the four irrigations was 16.62 inches and the average quantity retained in the upper six feet of soil was 4.51 acre-inches per acre, or 27.1 per cent of the total. Adding the estimated loss between irrigations and soil sampling, the average quantity retained in the upper six feet of soil for each of the four irrigations was 5.59 acre-inches per acre, or 34 per cent of the amount applied.

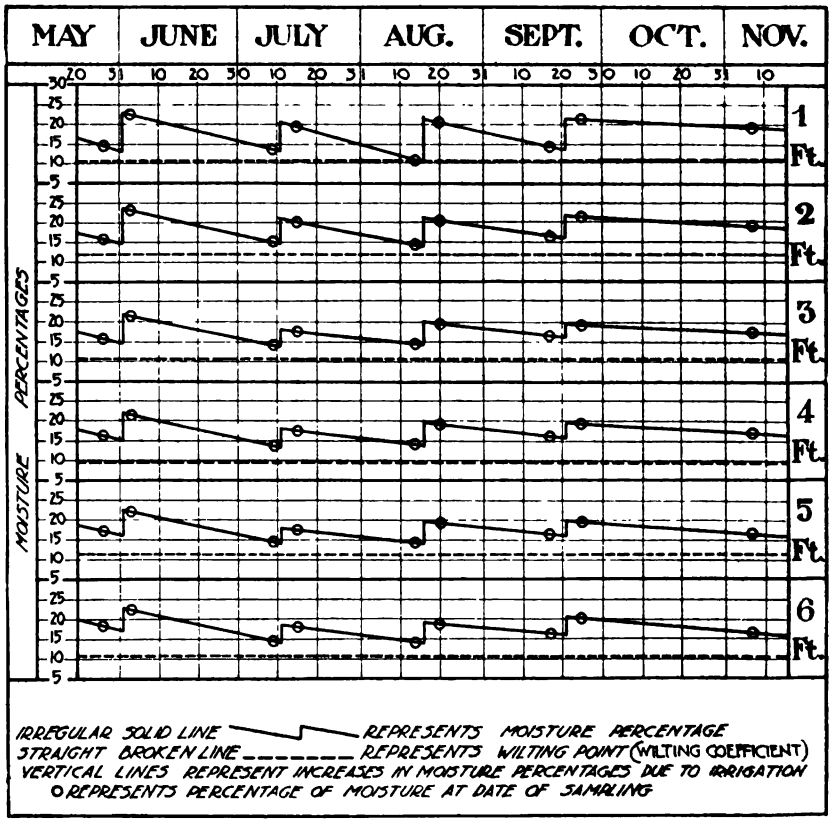


Fig. 7.—Diagram showing seasonal variation in soil moisture percentage, Hofhenke alfalfa field, Los Molinos, 1914.

Geer Field. Variations in soil moisture percentages in this field are shown in figure 8. The soil of this field is classed as a clay loam of the Vina series, the upper two feet being distinctly heavier than the underlying soil, which approaches a silt loam very closely. The diagram shows the wilting point was reached or closely approached in the latter part of July nearly to the full depth of the six feet sampled. Four irrigations were given in 1914, the respective depths applied being 24.00, 18.19, 12.15, and 24.34 inches. Twelve borings for mois-

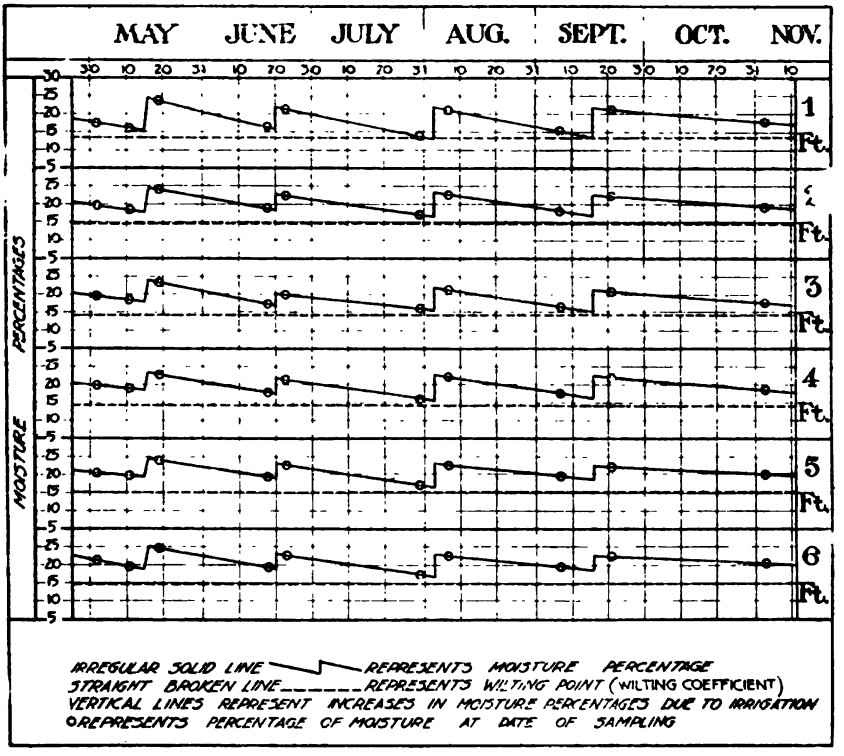


Fig. 8.—Diagram showing seasonal variation in soil moisture percentage, Geer alfalfa field, Los Molinos, 1914.

ture determinations were made to a depth of six feet before and after the first three irrigations and to a depth of nine feet before and after the fourth. These show that the upper six feet of soil retained 5.59 acre-inches per acre, or 23 per cent, at the first irrigation, 3.28 acre-inches per acre, or 18 per cent, at the second irrigation, 5.37 acre-inches per acre, or 44 per cent, at the third irrigation, and 3.76 acre-inches per acre, or 15 per cent, at the fourth irrigation. At the latter irrigation the upper nine feet of soil retained a total of 4.78 acre-inches per acre, or 20 per cent of the whole. The average depth applied at each of

the four irrigations was 19.67 inches, of which 4.50 acre-inches per acre, or 22.9 per cent, was retained in the upper six feet. With correction for the amounts lost between irrigations and the soil sampling, based on the Davis experiments, an average of 5.58 acre-inches per acre, or 28.4 per cent of the total, was retained in the upper six feet of soil.

TABLE No. 7.

Summary of Results of Alfalfa Duty of Water Investigations, Los Molinos Area, 1913.

Name	Soil type	Area, acres	Number of irrigations	Total depth water applied, feet.	Number of cuttings	Total yield, tons per acre
E. A. Bundy, No. 1	Silt, clay loam	8.97	4	4.91	5	3.02
E. A. Bundy, No. 2	Silt loam	4.31	4	6.06	5	7.86
R. W. Ballard	Silt loam	10.18	4	6.01	5	5.38
G. B. Engle	Light gravelly clay loam	17.15	5	4.46	5	3.78
G. H. Geer	Clay loam	9.21	4	7.41	5	7.84
J. F. Hofhenke	Silt loam	24.59	4	3.78	5	8.10
S. B. Reece	Clay loam	13.50	4	6.09	5	4.46
John Risse	Silt loam	15.00	4	6.38	5	5.58
A. Wigno	Silt loam	9.13	4	5.08	5	6.29
Averages				5.57		5.81

NOTE.—Rainfall at Red Bluff November 1, 1912, to October 31, 1913, 1.16 feet.

TABLE No. 8.

Summary of Results of Alfalfa Duty of Water Investigations, Los Molinos Area, 1914.

Name	Soil type	Area, acres	Number of irrigations	Total depth water applied, feet.	Number of cuttings	Total yield, tons per acre
E. A. Bundy, No. 1	Silt, clay loam	8.97	4	2.34	5	5.78
E. A. Bundy, No. 2	Silt loam	4.31	4	4.10	5	8.40
O. W. Chambers	Gravelly clay loam	3.08	6	1.42	6	4.44
G. B. Engle	Light gravelly clay loam	23.35	6	3.46	5	4.85
G. H. Geer	Clay loam	9.21	4	6.56	5	6.06
J. F. Hofhenke	Silt loam	13.27	4	8.46	5	5.75
	Silt loam	11.32	4	5.55	5	
S. B. Reece	Clay loam	13.50	4	5.47	5	5.68
A. Wigno	Silt loam	6.70	4	6.08	5	6.68
H. N. Woodward	Silt, clay loam	9.08	4	3.95	5	8.31
Averages				4.74		6.22

NOTE.—Rainfall November 1, 1913, to October 31, 1914, 2.74 feet.

DESCRIPTIONS OF FIELDS IN THE LOS MOLINOS AREA AND COMMENTS ON IRRIGATION CONDITIONS AND PRACTICES.

E. A. Bundy Field No. 1. Seeded in 1911. Stand of alfalfa fair. Field divided into seven border checks 80 to 90 feet by 630 feet, with average grade of four inches in 100 feet. Slope across some of checks is uneven, giving unequal distribution of water over surface. Small irrigation heads, ranging from one and one-half to two cubic feet per second, used, requiring more than two days to complete irrigation. Increased yields could have been obtained by better management, particularly by cutting alfalfa at proper time.

E. A. Bundy Field No. 2. Seeded in 1909. Stand of alfalfa good. Field divided into two parts by distributing ditch and every 30 to 40 feet cuts made in ditch bank through which water passes to field. Distribution not uniform over surface,

owing to high spots. Irrigation heads of one to two cubic feet per second applied once after each cutting, except fifth.

R. W. Ballard Field. Seeded in 1907. Stand fair but becoming thin in scattered spots. Field has not been checked and is irrigated by flooding from field ditches, which gives an unequal distribution. Irrigation head usually two and one-half to three and one-half cubic feet per second. Amount of water used on this field could be reduced materially by preparing the land in border checks. Several crops damaged by grasshoppers.

G. B. Engle Field. Seeded in 1911. Stand of alfalfa fair but field rather poorly prepared for irrigation. Irrigation head of one to two cubic feet per second divided into one or two checks varying greatly in size but averaging about 30 by 300 to 600 feet. Grasshoppers reduced yield in 1913.

G. H. Geer Field. Seeded in 1908. Field had excellent stand of alfalfa and considerable care exercised in preparing for irrigation. Border checks of 60 feet by 310 feet with average grade of about three inches in each 100 feet. Usual practice was to turn about five cubic feet per second into one or two checks. Excessive use of water due largely to the irrigator and abundance of water.

S. B. Reece Field. Seeded in 1908. Field had fair stand of alfalfa but not very well prepared. Checks rectangular, ranging from about one-fifth to three-fourths acre in extent. Average irrigation head of five cubic feet per second divided among two or three checks. Field was leased to tenants who did not exercise the best of care in applying water or in handling crop.

J. H. Hofhenke Field. Seeded in 1911. Stand excellent and land well prepared in border checks 40 feet by 400 to 450 feet, with average grade of five inches per 100 feet. Usually five cubic feet per second was divided between two checks.

A. Wigno Field. Seeded in 1911. Stand of alfalfa good, but land not very well prepared for irrigation. Field irrigated by flooding from field ditches, head varying from four to five cubic feet per second.

John Risse Field. Seeded in 1909. One of the oldest fields in the area and stand becoming thin. Field irrigated by flooding from field ditches with average head of five cubic feet per second. Distribution of water not uniform owing to slight irregularities in ground surface.

H. N. Woodward Field. Seeded in 1911. Stand good and land very well prepared for irrigation, except about one-fourth acre in northwest corner of field. Average irrigation head of five cubic feet per second usually divided between two border checks 60 feet by 330 feet.

O. W. Chambers Field. Seeded in 1911. Stand good and field well prepared in border checks 50 feet by 500 to 600 feet, with average grade of about two inches per 100 feet. Usually head of about one cubic foot per second turned into a single check.

Orland Area.

Investigations were conducted on five farms in the Orland area in 1913 and on eight farms in 1914, one of the latter, however, being part of one of the fields studied in 1913. (Fig. 9.) All of these fields lie within the Orland project of the Reclamation Service and the project manager assisted materially in the conduct of the work.

The Orland project comprises about 20,000 acres in Glenn and Tehama counties, of which 7,354 acres were irrigated in 1914. The average rainfall at Orland is 19.23 inches.[1] Irrigation water is obtained by the Orland project from Stony and Little Stony creeks, the direct

[1]Weather Bureau, Annual Summary for 1915.

flow being used when available in the early season, and storage at East Park Reservoir on Little Stony Creek being drawn on later. During the seasons of 1913 and 1914, owing to the fact that the project had not been opened formally by the Secretary of the Interior, irrigation water was supplied at a flat rate of $2 per acre. The land in the project, as thus far irrigated, is largely of gravelly nature, which, with an average slope toward the southeast, of 10 to 15 feet to the mile, supplied adequate drainage. Owing to the gravelly character of the land under irrigation, up to the end of 1914, when more land was taken in, it was found impractical to trace the underground movement of the irrigation water applied, with the exception of the O'Hair farm, on which observations of this nature were made in both 1913 and 1914. All measurements of use in the investigations were made by means of Cipolletti or rectangular weirs, and automatic registers were installed on six of the farms. All of the land in the Orland project is in private ownership. Up to 1914 the average individual cropped area was 22 acres. Alfalfa, the only crop covered in the investigation, is the principal crop grown, although practically all of the fruits raised in California are grown commercially to more or less extent in this project.

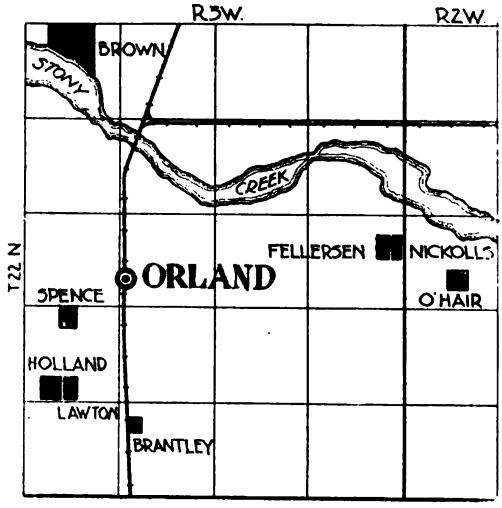


Fig. 9.—Map of Orland area showing location of alfalfa fields under investigation, 1913 and 1914.

The total depth of water applied in 1914, as indicated in tables Nos. 9 and 10, is greater than that applied in 1913, due to a larger supply being available. The yields were larger in 1914 than in 1913, due both to this increased supply and probably also to the very much larger rainfall in 1914. The widest variation in relation between the amount of water applied and the crop yield occurred on the Lawton farm, where 4.29 acre-feet of irrigation water per acre and .82 foot of rainfall produced 5.29 tons of alfalfa in 1913, whereas 9.59 acre-feet of irrigation water and 2.39 feet of rainfall in 1914 increased the yield over 1913 only about 10 per cent. Soil moisture determinations are not necessary in cases of this kind to indicate the needless waste of applying so much water as was applied to the Lawton field in 1914. Fortunately the excessive use in 1914 was but the temporary practice of a renter.

The tracing of the underground distribution of the irrigation water applied in the Orland area was confined to the O'Hair field (Fig. 10), the other fields being eliminated from this work because of the gravelly nature of the soil. The soil of the O'Hair tract lies near the border line between a silt loam and clay loam and is somewhat impregnated with fine gravel at a depth of three to five feet, a coarser gravel being sometimes encountered at a depth of about eight feet.

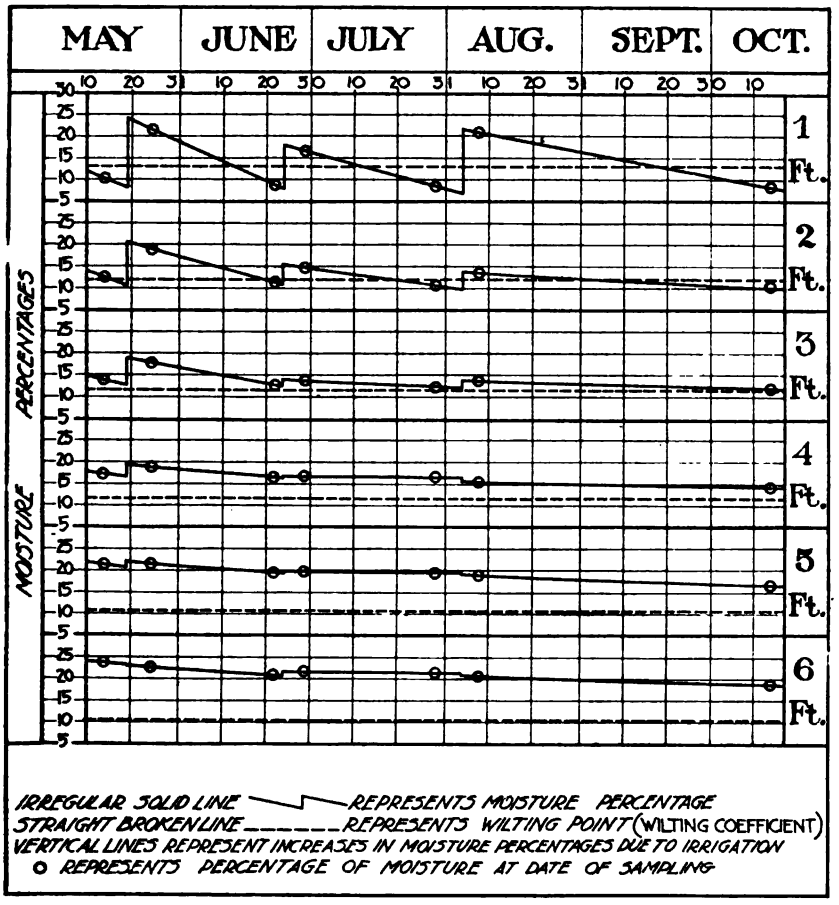


Fig. 10.—Diagram showing seasonal variation in soil moisture percentage, O'Hair alfalfa field, Orland, 1914.

Owing to changing from the sun-dried to the oven-dried method of making moisture determinations, the work of this nature in 1913 was not conclusive. The field received three irrigations in 1914 and nine borings for moisture determinations were made to a depth of six feet before and after each irrigation. In the first irrigation a depth of

6.24 inches was applied, of which the upper six feet retained 3.58 acre-inches per acre, or 57 per cent of the amount applied. Of this about one-half was retained in the surface foot. At the second irrigation a depth of 3.18 inches was applied, of which 2.11 acre-inches per acre, or 66 per cent, was retained in the upper six feet, nearly two-thirds of this remaining in the surface foot. In the third irrigation, a depth of 3.24 inches was given, of which approximately two-thirds remained in the upper six feet, nearly all of this remaining in the surface foot.

The striking condition brought out by the moisture borings in the O'Hair field was that, while the percentage of the irrigation water applied retained in the soil decreased with the depth, the amount of moisture in the soil before irrigations actually increased with the depth, apparently due to the capillary rise of ground water, which stood seven to nine feet below the surface. As a whole, the moisture percentages in the upper three feet of soil did not vary widely from the amount necessary to prevent wilting, and below three feet it was at all times well above the wilting point.

TABLE No. 9.

Summary of Results of Alfalfa Duty of Water Investigations, Orland Area, 1913.

Name	Soil type	Area, acres	Number of irrigations	Total depth water applied, feet	Number of cuttings	Total yield, tons per acre
David Brown	Gravelly clay loam	76.45	7	4.73	[1]3	3.98
C. E. Fellerson	Coarse gravel impregnated with silt and wash loam	32.45	9	2.83	[2]4	4.44
H. M. Lawton	Coarse gravel impregnated with loam	18.61	9	4.29	[2]4	5.39
Roy O'Hair	Silt loam	34.20	5	3.16	[2]4	6.40
A. C. Spence	Coarse gravel impregnated with silt and wash loam	8.06	10	3.91	[2]4	4.85
Averages, not counting field injured by caterpillars				3.55		5.12

[1]Fourth crop destroyed by caterpillars.
[2]Only four crops cut, due to shortage of water.
NOTE.—Rainfall November 1, 1912, to October 31, 1913, 0.82 foot.

TABLE No. 10.

Summary of Results of Alfalfa Duty of Water Investigations, Orland Area, 1914.

Name	Soil type	Area, acres	Number of irrigations	Total depth water applied, feet	Number of cuttings	Total yield, tons per acre
David Brown	Gravelly clay loam	76.45	7	5.04	5	5.49
R. F. Brantley	Clay loam	7.75	18	4.08	5	6.18
O. E. Fellerson	Coarse gravel impregnated with silt and wash loam	14.79	8	2.59	5	5.87
H. M. Lawton	Coarse gravel impregnated with loam	13.61	13	9.59	5	5.84
E. F. Nicholls	Coarse gravel impregnated with silt and wash loam	16.66	9	3.25	[1]4	5.26
J. E. Holland	Coarse gravel impregnated with loam	37.00	13	7.56	5	6.26
Roy O'Hair	Silt loam	34.20	3	1.04	[1]4	7.17
A. C. Spence	Coarse gravel impregnated with silt and wash loam	27.70	10	5.56	Pasture	
Averages, not counting fields partially or wholly pastured				5.76		5.92

[1]Crop pastured after fourth cutting.

NOTE.—Rainfall November 1, 1913, to October 31, 1914, 2.39 feet.

DESCRIPTIONS OF FIELDS IN ORLAND AREA AND COMMENTS ON IRRIGATION CONDITIONS AND PRACTICES.

David Brown Field. Seeded in 1909. Land in contours, average difference of elevation between checks being seven inches. In many places uneven grading was cause of scattering and poor growth of alfalfa. Variation in character of soil also had a marked effect upon yield, particularly in south half of field, where soil is compact and in spots quite impervious to water. Average head of water delivered varied from four to eight or nine cubic feet per second, divided so that about one to two cubic feet per second was used on each check. Seven irrigations given each year, 1914 showing slight increase in total application over 1913.

R. F. Brantley Field. Seeded in 1912. Stand of alfalfa fair. Field in square checks having average length and width of about 150 feet. The compact clay loam soil is typical of the project, requiring light, but frequent, irrigations. Water applied every eight or ten days throughout irrigation season, with total of 18 applications. Average amount of water applied each time was a little less than three acre-inches per acre. Soil sampling showed that in some parts of the field water penetrated only from 12 to 15 inches, while in other parts there was a fairly uniform moisture distribution to depth of six feet. A short growth of alfalfa always showed spots where moisture was deficient.

Fellerson-Nicholls Fields. Seeded in 1909. In 1913 this tract was subdivided, the east half being purchased by E. F. Nicholls, so that in 1914 records were kept of each piece separately. Stand of alfalfa good. Field originally prepared in border checks 20 to 40 feet by 100 to 1,400 feet, but by constructing a new head ditch through middle of field the maximum length of checks was reduced to 700 feet. Average irrigation head varied from five to seven cubic feet per second, divided into two or three checks. The greater use of water on Nicholls field is attributed largely to lack of experience of the irrigator.

H. M. Lawton Field. Stand of alfalfa good. Field in square checks averaging about one-fifth acre each. The soil of this tract is so well aerated and drained that irrigation can be followed almost immediately by the mower. Field irrigated 13 times in 1914 at intervals of 12 to 14 days, with average irrigation head of 10 to 12 cubic feet per second. Persons who rented this field in 1914 were careless in handling water and used more than necessary.

J. E. Holland Field. Seeded in 1910. This field lies immediately west of Lawton field and has good stand. Field was irrigated about every 14 days with average head of 9 to 11.5 cubic feet per second turned into one or two checks having an average area of one-fifth acre. This proved the most economical way of applying water. Field is so well drained and soil so porous that the water of an irrigation immediately disappears; it was not unusual for owner to cut alfalfa within a half day after water was applied.

Roy O'Hair Field. Seeded in 1910. Stand excellent. Field in border checks about 40 feet by 300 to 1,250 feet, with average grade of 2½ to 8½ inches in 100 feet. Average irrigation head of 7½ cubic feet per second was turned into two or three checks. During 1914 water table was five to six feet below surface, but in the previous year was at depth of eight feet. It was customary to irrigate this field once after each cutting, but in 1914 owner, being afraid of the rising water table, irrigated only three times in the season. Fifth crop of alfalfa was pastured.

A. C. Spence Field. Seeded in 1912. Stand of alfalfa fair. Field in checks about 100 feet square so arranged in relation to field ditches that an irrigation head of five to eight cubic feet per second can be admitted directly into each check. Owing to the extreme porosity of soil, there was little growth of alfalfa on any part of field except that actually receiving water at each irrigation. Two years studies on this tract showed that unless at least five cubic feet per second is turned on a check of coarse gravelly soil, much of water will be lost through percolation before check is covered.

Willows Area.

Investigations were conducted in this area on six farms in 1914, of which five received water from Central Canal. (Fig. 11.) The work was confined to certain heavy types of soil not represented in the investigations elsewhere in the valley and work was hardly under way in 1914 before the fact was revealed that much difficulty was being experienced in getting water to penetrate the soil. The heavy soils encountered are classified in the Soil Survey as Tehama clay and clay loam.[1] These soils are all of compact structure and inclined to be refractory, very sticky when wet, and subject to hard baking in drying. In local areas, drainage is poor and in winters of heavy rainfall considerable damage is done to alfalfa fields by standing water. In some cases in 1914 it was found immediately after irrigation that water which irrigators supposed was penetrating sufficiently deep to meet all water requirements of the plants was in fact penetrating to depths of only 10 to 12 inches below the surface.

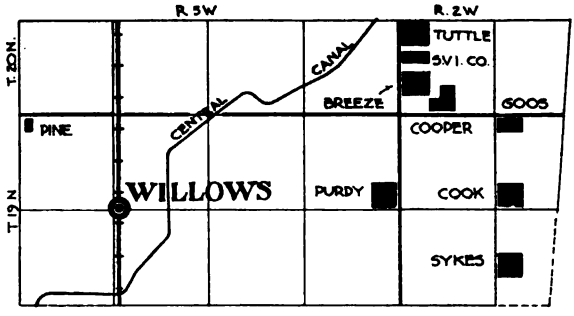


Fig. 11.—Map of Willows area showing location of alfalfa fields under investigation, 1914 and 1915.

[1] U. S. Dept. Agr., Bureau of Soils, Reconnoissance Soil Survey of the Sacramento Valley, California.

The average rainfall at Willows, over a three-year period only, is 16.55 inches.[1] Water carried by Central Canal is obtained by pumping from Sacramento River, except that in the spring and early summer the supply comes from the flood flow of Stony Creek. In 1914 the charge for water was 90 cents per acre and in 1915 it was $1.50 per acre, regardless of time and amounts of application. In general, the border method of preparing land for alfalfa has been followed here, the checks usually being 30 to 60 feet wide and 400 to 800 feet long, with a drain ditch usually provided in the best fields at the lower ends of the checks. Heads of water delivered to the irrigators ranged from three to seven cubic feet per second. In 1914 there was no uniformity in the number of applications given alfalfa, some watering four times and others ten times.

The difficulty encountered in obtaining sufficient moisture penetration in the heavy Willows soils in 1914 suggested the desirability of a continuation of the investigations through the season of 1915 under conditions that would be typical, and where it would be possible to vary the method and time of application. Accordingly, a suitable field was selected five and one-half miles northeast of Willows, and while this work was going on at this field, observations of use alone also were made on four other fields, as reported in Table No. 12.

As compared with the amounts of water used and the result in yields of alfalfa on the other farms under observation in the valley during these investigations, both the use and the yields on the soils under observation about Willows were low—an average use of 1.83 acre-feet of water per acre and an average yield on six farms in 1914 of 4.82 tons per acre. It is to be noted from tables Nos. 11 and 12 that in no case was more than 1.97 acre-feet of water applied, and that in no case, so far as measured, did the yields obtained exceed 5.39 tons per acre. The reasons for these results are not difficult to find when account is taken of the soil moisture determinations made in 1914 on the Purdy, Tuttle, and Pine fields, and in 1915 on the special experimental field northeast of Willows.

Purdy Field. The soil in this field is classed as Tehama clay and is unusually compact. The field was irrigated four times in the season. Three borings for soil moisture determinations were made before and after the first irrigation, eight before and after the second irrigation, and six before and after the third and fourth irrigations. Of the 7.08 inches in depth applied in the first irrigation about 12 per cent entered and was retained in the upper three feet of soil, of which about 11 per cent was in the upper foot. In other words, practically no moisture penetrated below 12 inches. In the second irrigation a depth of 4.56

[1]Weather Bureau, Annual Summary for 1915.

inches was applied, nearly all of which penetrated the soil and of which about 45 per cent remained in the upper foot. In the third irrigation a depth of 4.80 inches was applied, of which approximately one-third remained in the upper foot, with no increase below the second foot. The moisture determinations before and after the fourth and last irrigation, when a depth of 3.84 inches was applied, indicated that the soil became more impervious to water as the season advanced, for about 66 per cent of the amount applied was retained in the first foot, with no significant increase below that.

In comparing the amount of moisture in the surface foot of soil in this field with the amount necessary to maintain plant growth without witling (Fig. 12), it is found that the variation was from three or four per cent below to five or six per cent above that amount through the

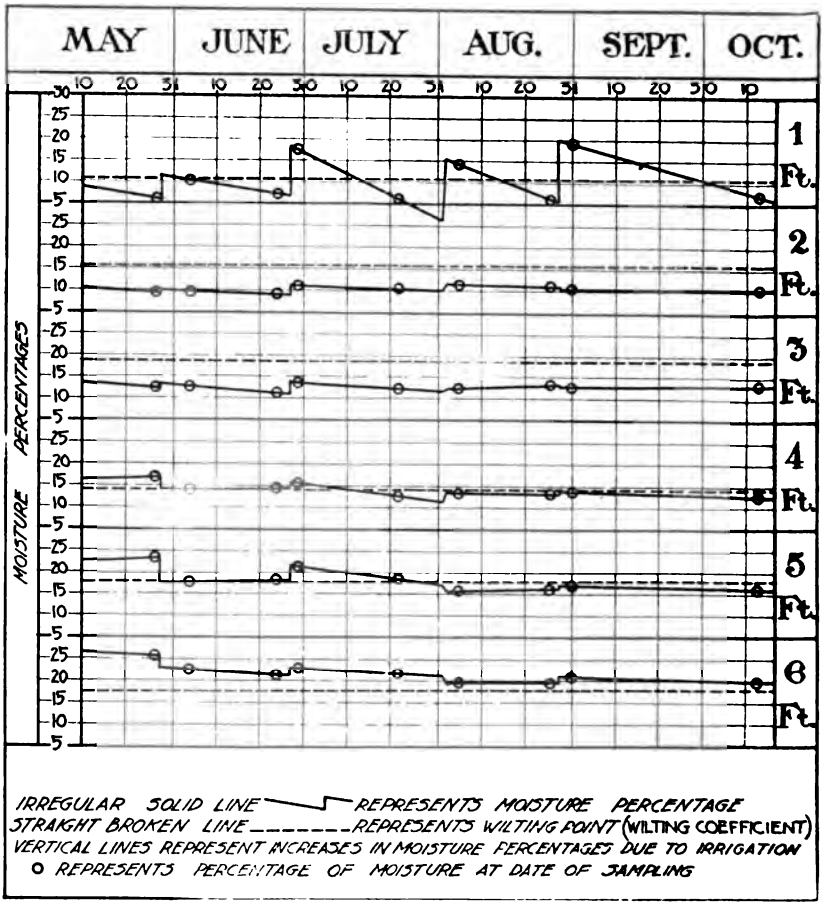


Fig. 12.—Diagram showing seasonal variation in soil moisture percentage, Purdy alfalfa field, Willows, 1914.

season. At no time in the season was the moisture percentage in the second and third foot sections sufficient in itself to prevent wilting, averaging about four per cent below, but at depths of four to six feet there was almost enough to do so.

The most rapid growth of alfalfa in this field occurred during May, when the second crop was being produced. After this the rate of growth decreased continuously, until at the time of the fourth crop. These facts as to growth, taken with the low yield, add to the evidence that the crop suffered through failure of the irrigation water to penetrate the soil below the first foot or two.

Tuttle Field. The soil is similar to that of the Purdy field, but slightly coarser in texture and a little more open and permeable. Moisture determinations were made from ten borings before and after the second irrigation and from nine before and after the third irrigation, a depth of 4.08 inches being applied in the first case, and of 4.16 inches in the second and third. At the second irrigation 93 per cent of the water applied was found to enter the first three feet of soil, about one-half being retained in the first foot. In the third irrigation 44 per cent was retained in the first six feet, three-fourths of which remained in the first foot.

Pine Field. The soil in this field is classed as Willows clay adobe, which was found to be less impervious to water than the Tehama clay of the Purdy and Tuttle fields, and less difficult to handle. Moisture determinations were made from six borings before and after each of the second, fourth and sixth irrigations, the depth of water applied at these irrigations having been 2.40, 3.72, and 4.32 inches, respectively. At the second irrigation all of the water appeared to be held in the first six feet, with approximately one-half retained in the first foot. Of the fourth irrigation about 60 per cent entered the upper six feet, and of this 49 per cent remained in the surface foot. In the case of the sixth irrigation 90 per cent was found to enter the upper six feet, of which nearly one-half again remained in the surface foot.

Experiments in 1915.

In continuing the study on a typical field in 1915 the plan adopted was to give equal total applications of irrigation water to all plats under observation, but to vary the time, depth, and frequency of irrigations. The land used in the experiment was furnished rent free by the local irrigation company, together with irrigation water, while this office met the full expense of the field investigation. The field utilized in this study, with roadways and main canal eliminated, comprised 8.75 acres of alfalfa divided into 21 border checks 60 feet by 300 feet, with an average grade of four inches per 100 feet, and with an average area

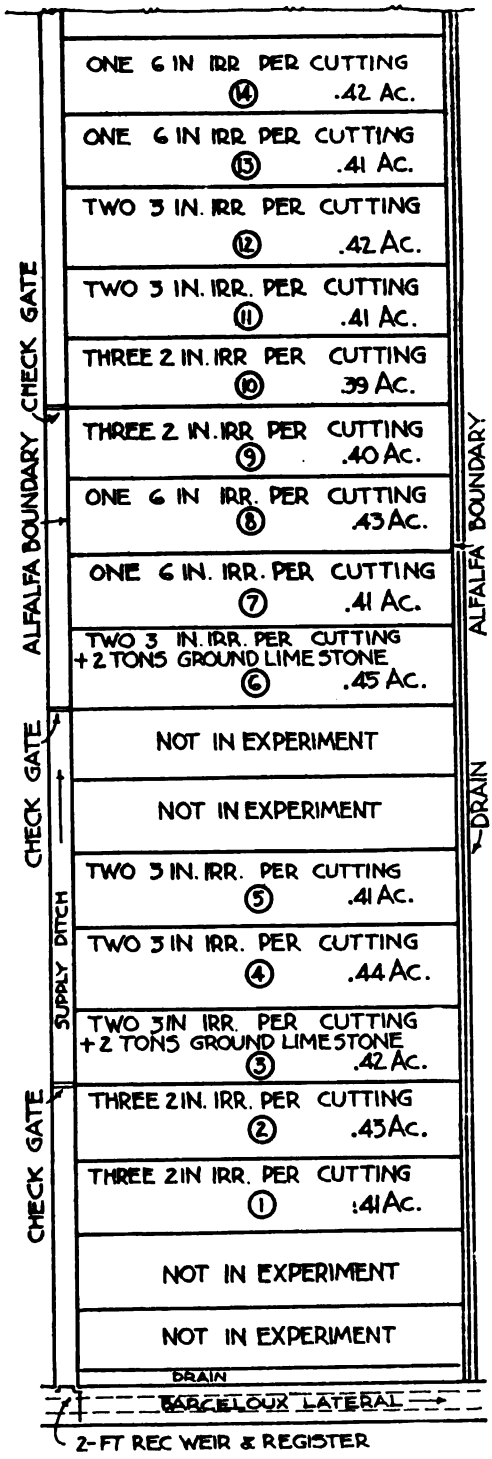


Fig. 13.—Plat of experimental tract, Willows, 1915.

per check of 0.42 acre (Fig. 13.) A drain ditch parallel with the head ditch cared for surface run-off from the lower ends of the checks. The alfalfa was seeded in 1911, following many years of dry grain cropping, and while the stand was not good at the time of these experiments, it was one of the best that could be found on the compact soils of the neighborhood, and, in general, was representative of many alfalfa fields of the locality. At the lower ends of the checks small areas of alfalfa had been killed in previous years by standing water, and these small areas and a considerable number of bare places on the levees and parts of the checks where the stand was comparatively thin were partially responsible for the low yields obtained. Except for the wide distances between the check levees, the field was well prepared for irrigation.

The soil in this field, which is classed as a Tehama clay loam, is grayish in color and of compact structure and refractory nature. When wet it is sticky, and upon drying becomes very hard, but does not check or crack. It is free from both hardpan and gravel and little difference is noticeable between the soil and subsoil. This type of soil was selected because the soil survey maps indicate the presence of about 45,000 acres

of it in Sacramento Valley, very largely east of Willows in the area surrounding this field.

The amount of water used on each of the plats during the season was two acre-feet, an average irrigation head of 2.82 cubic feet per second being generally divided between two checks, although various other sizes of heads were tried. One-third of the twelve checks under observation were irrigated with a depth of six inches, once for each cutting except the last, one-third received two three-inch irrigations between cuttings applied just before and just after the crop was removed, and one-third received three two-inch irrigations, at intervals of about 12 days. (Plate II, Fig. 1.) All of the water entering the field was measured by a 2½-foot rectangular weir and automatic register. (Plate II, Fig. 2.)

For the purpose of increasing, if possible, the perviousness of the soil to water, two checks were treated with ground limestone at the beginning of the season at the rate of four tons per acre. It was not expected that these checks would show much change the first year and they did not. The largest annual yield of alfalfa, 5.07 tons per acre, was obtained from the checks receiving three two-inch irrigations per cutting, an increase of 18 per cent over the lowest yields, 4.42 tons per acre, being secured from the checks that received two three-inch irrigations per cutting, and lowest yield, 4.29 tons per acre, coming from the checks irrigated with one six-inch irrigation per cutting.

While the above increases of yield indicate the desirability of more than one irrigation per cutting, the differences in the one season of investigations were not great. It was evident to those in the field, however, that the more frequent the application of water, the better the moisture condition of the soil. Borings for soil moisture determinations were difficult, except immediately after irrigations, and even then difficulty was encountered below the first foot of soil. Including the 12 plats, a total of 3,408 moisture determinations were made before and after irrigations, and while the chief value of these is in the larger understanding they give of the character of these compact soils, especially with reference to the permeability to irrigation water, they substantiate, to the extent reasonably to be expected, the better results due from the more frequent applications of irrigation water.

In order to gain an idea of the root development of the alfalfa in this field a hole about six feet square and three feet deep was excavated. This also afforded a good view of the cross section of the soil formation. The roots of the plants were carefully removed. It was found that the taproots of the alfalfa were not over one-half inch in diameter and did not extend below a depth of three feet. The main mass of the roots was concentrated in the upper two feet of

soil. The fact that the greater part of the alfalfa plants in this particular field are shallow-rooted is attributed largely to the compact structure of the soil, making moisture penetration difficult.

After removing the soil for root examination some rather surprising results were found in tests made by filling the hole from which they came with water and noting the time required for downward and lateral percolation. Twenty-four hours after the hole had been filled to a depth of three feet there remained in the hole two feet of water. Two weeks later there still remained one foot. Holes two inches in diameter and four feet deep bored 12 inches away from the large test hole showed no lateral percolation. In holes bored six inches from the test hole a slight amount of water had seeped through after 12 hours. Later another hole was excavated in a different part of the field and similar trials made, practically the same results being secured as in the first test. These tests serve to show the impermeability and peculiar physical conditions of the soil represented in this field.

TABLE No. 11.

Summary of Results of Alfalfa Duty of Water Investigations, Willows Area, 1914.

Name	Soil type	Area, acres	Number of irrigations	Total depth water applied, feet	Number of cuttings	Total yield, tons per acre
P. S. Cook	Silty clay loam	15.65	9	1.68	[1]3	1.71
C. F. Goos	Silty clay loam	13.00	10	1.83	5	5.32
L. E. Tuttle	Silty clay loam	35.06	4	1.28	[1]3	3.93
V. E. Breeze	Silty clay loam	35.95	6	1.79	[1]3	1.63
Jas. Purdy	Silty clay	11.37	4	1.69	5	3.75
W. B. Pine	Clay adobe	3.34	7	1.97	4	5.39
Averages, not counting fields pastured				1.83		4.82

[1]Crop pastured after third cutting.

NOTE.—Rainfall November 1, 1913, to October 31, 1914, 2.39 feet.

TABLE No. 12.

Summary of Results of Alfalfa Duty of Water Investigations, Willows Area, 1915.

Name	Soil type	Area, acres	Number of irrigations	Total depth water applied, feet
C. F. Goos	Silty clay loam	13.00	7	1.62
L. E. Tuttle	Silty clay loam	35.06	5	1.75
Geo. Cooper	Silty clay loam	3.01	7	1.53
H. J. Sykes	Silty clay loam	15.60	7	1.94
Average				1.71

NOTE.—Rainfall November 1, 1914, to October 31, 1915, 2.09 feet.

PLATE II.

Fig. 1.—Irrigation of alfalfa on Willows experimental tract, 1915.

Fig. 2.—Weir and water register, Willows experimental tract, 1915.

DESCRIPTIONS OF FIELDS IN THE WILLOWS AREA AND COMMENTS ON IRRIGATION CONDITIONS AND PRACTICES.

P. S. Cook Field. Seeded in 1912. Stand thin in spots but compares rather favorably with other fields in the vicinity. Field irregular in shape and is divided into border checks 40 to 80 feet wide and from 200 to 700 feet in length, with average grade of 3 inches per 100 feet. An irrigation head of 3.5 to 6 cubic feet per second divided between two and four checks. Miscellaneous borings after irrigation showed little moisture below a depth of 12 to 15 inches.

C. F. Goos Field. Seeded in 1911. Stand comparatively good. Land in border checks 40 feet by 600 feet with average grade of 12 inches per 100 feet. Grade is excessive for heavy soil found here. Average heads of five to six cubic feet per second divided into two or four checks. Much care used in irrigating and only enough water added to reach lower end of checks without surface waste.

L. E. Tuttle Field. Seeded in 1907. Stand is among the best in area. Field has not been checked, irrigation being carried on by flooding from field ditches 200 feet apart. Portable canvas check gates are used to back up water in field ditches and are so placed that water spreads over a distance of about 200 feet at one time. Heads of four to seven cubic feet per second were divided into two ditches.

V. E. Breese Field. Seeded in 1907. This field had been utilized for pasture for several seasons and stand was rather poor. Contour method used, checks ranging from three-fourths acre to two acres. Distribution of water over field uneven owing to poor grading. Average head of three cubic feet per second used and sometimes divided into three or more streams.

James Purdy Field. Seeded in 1912. Stand uneven and has been damaged in various spots by water standing on surface and poor drainage. Land in border checks 30 feet by 650 feet with average grade of about two inches per 100 feet. Heads of two or four cubic feet per second were used, one cubic foot per second usually being turned into each check. Despite the fact that small heads were permitted to run a long time over the land, it was difficult to place any appreciable amount of water below a depth of 12 to 15 inches.

W. B. Pine Field. Seeded in 1913. Stand good and land well prepared in border checks 30 feet by 400 feet, with average grade of about nine inches per 100 feet. Water was obtained from small pumping plant and an average flow of .3 to .45 cubic foot per second was turned into a single check. Moisture determinations showed that a more uniform distribution of water probably could be attained either by increasing the discharge from the well or by reducing the length of the checks.

George Cooper Field. Seeded in 1914. Stand comparatively good and land fairly well prepared in border checks 40 feet by 622 feet, with average grade of five inches per 100 feet. An average head of one and one-half cubic feet per second was turned into a single check.

H. J. Sykes Field. Seeded in 1913. Stand not uniform, there being small areas, especially at lower end of checks, where crop has been drowned. Land is in border checks 40 feet by 600 to 950 feet, with average grade of two and one-half inches per 100 feet. An average irrigation head of four to five cubic feet per second was divided among two or three checks. Difficulty was experienced in getting water to penetrate soil to any considerable depth.

Woodland Area.

Woodland is situated south of Cache Creek, in Yolo County, on the west side of Sacramento Valley. The mean annual rainfall at Davis, nine miles south, is 17.23 inches.[1] The water supply for irrigation is derived from Cache Creek by gravity and pumping, and by pumping from wells and from Willow Slough. Cache Creek forms

[1]Weather Bureau, Annual Summary for 1915. A record kept at Woodland by the Weather Bureau from 1873 to 1909 gave a mean of 17.73 inches.

the only outlet to Clear Lake, wherein it is proposed to store a large supply of water for power and irrigation by means of a dam recently completed. At the time the duty of water investigations were being conducted this dam had not been completed and only the direct run-off was available. The company controlling the Cache Creek supply diverts water from Cache Creek in three places, that for the immediate Woodland section being taken out at Moore Dam, about seven miles west of Woodland. Water is delivered in rotation at $1.50 per acre-foot. Measurement is made in submerged-orifice boxes, or by current meter or surface float. Considerable pumping development has taken place in the area since early in 1911, at which time electric power came into general use in this section, and during the four years ended with 1914, 77 pumping plants were installed for irrigation. The soils, which are residual from Cache Creek, consist of the Yolo series as mapped by the Bureau of Soils and the University of California and range from fine sandy loams to clay loams.[1] Alfalfa is the principal crop grown under irrigation. The average of 22 yields in 1913 and 1914 distributed among five cuttings was 1.84, 1.51, 1.10, 1.22 and .59 tons per acre, respectively, a total of 6.26 tons per acre. The relatively low average for the third cutting was caused by grasshopper devastations in 1913 and in some instances by failure to irrigate until after the third cutting in 1914. Prunes usually are irrigated every year, but other fruits and grain are irrigated only in years of deficient rainfall.[2]

The number of irrigations in a season around Woodland is normally dependent directly upon the preceding winter's rainfall, and the practice is to begin irrigation with the first, second or third crop of alfalfa, according to the dryness or wetness of the season, and to irrigate each crop thereafter, usually as soon as the preceding crop has been removed. The abnormally light rainfall in 1912–1913 had two different effects upon irrigation practice; it made irrigation necessary to mature even the first crop of alfalfa, and it caused the water supply to run short in the summer. Water was abundant early in the season and could be had practically on application, but later the very small quantity available had to be rotated among many irrigators, with the result that some crops were half grown before irrigation and others received no water at all. This, of course, had the effect of diminishing the

[1] U. S. Dept. Agr., Bureau of Soils, Reconnoissance Soil Survey of the Sacramento Valley, California.

[2] Investigations made of grain irrigation in this area in 1913 and 1914 showed a total of 2,419 acres of barley, oats, and wheat irrigated in 1913 as a result of deficiency in rainfall, and only 12 acres irrigated in 1914 after a winter of very heavy rainfall. An average of 1.11 acre-feet per acre was applied in 1913, generally in one irrigation, and the average yield of grain was 23 sacks per acre from irrigated fields and about 8 sacks per acre from unirrigated fields. In 1914 the average yield from the same tracts unirrigated was 22 sacks per acre. Thus with a relatively small additional expenditure the yield in 1913 was more than doubled by irrigation and was made to equal that in 1914, a season of abundant precipitation and normal growing conditions.

yields of hay. Following a winter of very heavy rainfall, however, the first and second crops in 1914 were grown without irrigation, and water was plentiful throughout the season. Nevertheless, owing to the low price of hay, most growers irrigated only once or twice in 1914 and some not at all, whereas the normal practice would have been to irrigate after the second, third and fourth cuttings. Of the fields under observation the only ones irrigated three times were supplied by pumping plants. Thus the possible increase in yields due to a better water supply was curtailed.

The border check is the most common type in this area. The checks are usually 40 to 60 feet wide and 650 to 1,300 feet long, depending upon the shape and size of the field, with a single supply ditch skirting the higher end, but with occasionally a cross lateral located halfway down. Under pumping plants with their smaller heads of water, checks generally are 20 to 35 feet by 100 to 600 feet. The grade of checks varies normally from 1.8 to 4.8 inches and averages about three inches in 100 feet. Levees vary in height from nine inches to two feet and in width from 6 to 12 feet. Field laterals under the gravity system are large, almost invariably measuring 18 feet from center to center of ditch banks, with the ditch bottom about one foot below the adjoining field level. Check gates are of both wood and concrete and usually from six to eight feet wide in order to admit large heads of water, to insure more rapid spreading, and relieve the pressure of water on the ditch banks. The heads of water delivered to individual farms are among the largest in California, ranging normally from 10 to 20 or 25 cubic feet per second, but these quantities usually are divided among two or three checks. The size of head is limited in times of water abundance only by the capacity of the field lateral. Canvas dams are used in the farm ditches for diverting water into the checks, a check 650 feet long and of average grade requiring about an hour to irrigate. Usually two men are employed in irrigating a field of 20 acres and an extra man where fields are larger.

Duty of water observations were made in the Woodland area in 1913 on 12 fields of alfalfa (Fig. 14), one prune orchard and one grain field. In 1914 the investigations were confined to alfalfa, and although the total number of alfalfa fields under observation was less in 1914 than in 1913, several were divided into plats and a separate study made of each plat, so that the effective number of fields in 1913 was 13. Measurements of the heads of water used were made in all cases under the canal system and under the Jackson-Woodard pumping plant by current meter, in most cases in flumes. Under the Fisher pumping plant, measurements were made with a rectangular weir.

Speaking generally regarding the results of measurements of use in the Woodland area, it can be said that because charges for irrigation

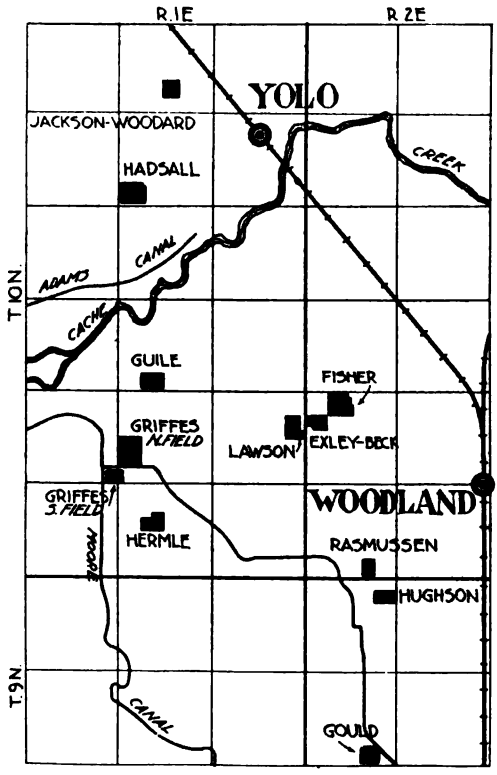


Fig. 14.—Map of Woodland area showing location of alfalfa fields under investigation, 1913 and 1914.

water are based directly on the quantities used rather than on the number of acres irrigated, irrigators seem more inclined to irrigate with reference to the immediate profits to be obtained for each crop than under any of the other gravity systems included in the investigation. In years of normal rainfall and for a limited number of years, fairly satisfactory crops of alfalfa are obtained around Woodland without irrigation, and when the market price of alfalfa is not high farmers frequently do without more than one or two waterings. The average total application in 1913 was 2.94 acre-feet per acre, the rainfall for that year having been 0.61 foot and the price of alfalfa relatively high. The average application per irrigation that year was 0.85 acre-foot per acre. In 1914, when the seasonal rainfall was 2.45 feet and the price of alfalfa was low, the average total application was only 1.80 acre-feet per acre, with the average application at single irrigations 0.99 acre-foot per acre. Thus the results in this area in 1913 show typical use in a year of great demand for water and of limited supply, together with a high average price for alfalfa, while in 1914 they show typical use in a season of ample water supply and minimum incentive to alfalfa production.

With equivalent total applications of water in the Woodland area, the yields generally were greater on the heavier soils than on the lighter soils, undoubtedly due to some extent to the greater moisture retentive capacity of the heavier soils. While the average yield of hay per acre from the irrigated fields under observation in 1914 was 6.75 tons, the average yield from three unirrigated fields in the same year was only 3.66 tons. In 1913 the duty of water was generally higher on the finer textured soils, and this held true for single irrigations in 1914, also.

Soil moisture determinations were made in the Woodland area in 1913 before and after one irrigation on the Lawson field and before and after three irrigations on the Jackson-Woodard field. In 1914 determinations were made at each cutting and before and after each irrigation on the Hughson, Beck, Griffes, Guile, and Jackson-Woodard fields. The average proportion of each application of water accounted for in the first six feet of soil was 36 per cent for the lighter soils, 44 per cent for the medium soils, and 56 per cent for the heavy soils, indicating in each case that the amounts of water applied were greater than could be held where probably most needed. On the other hand, the results indicated that in many cases, in spite of the excessive applications between cuttings, the moisture content present was inadequate at times, due to the too great interval between irrigations.

Hughson Field. (Fig. 15.) The soil of this field is classed as Yolo silt loam. Moisture determinations in 1914 were made from 12 borings before and after the first irrigation, from six borings after the second irrigation, and from six borings at the first, second and fifth cuttings. Taking the field as a whole, the percentage of moisture in the soil at the beginning of the season was well above the amount necessary to maintain growth, but fell below the wilting point in a portion of the upper six feet of soil by the time of the second cutting, and in the entire upper six feet by the time the third crop was two-thirds grown, when the first irrigation was given. This first irrigation brought the moisture content back to the desired point but it went down again below the wilting point by the time of the fourth cutting, after which the second irrigation was given. At the first irrigation a depth of 26.2 inches of water was applied. The greatest increase in moisture content due to this irrigation was between the sixth and the ninth foot in depth, as determined six days following the application, with the limit of penetration somewhere below 12 feet. Of the 26.2 inches applied at this first irrigation, only 10.23 acre-inches per acre, or 39 per cent, was accounted for in the upper 12 feet, with only 20 per cent of the total application accounted for in the upper six feet. In a general way the same results were indicated from the moisture determinations following the second irrigation. The fact that only about one-fifth of the water applied can be accounted for in the upper six feet of soil, and no more than two-fifths in the upper 12 feet of soil, is evidence that through too deep penetration at the upper ends of the checks, much water is wasted in attempting to irrigate the lower ends of the long checks—1,270 feet in this field.

Lawson Field. The soil in this field is classed as a silt loam. Moisture determinations were made from eight borings before and after the third irrigation in 1913, at which irrigation a depth of 7.32 inches

was applied. Of this, 2.56 acre-inches per acre, or 35 per cent, was found in the upper six feet, with two-fifths in the surface foot. An appreciable portion of the water applied undoubtedly penetrated below six feet in depth, but under the present conditions it is reasonable to assume that the greatest loss was due to evaporation during the extremely hot weather prevailing at the time. In general, the determinations indicate a lack of uniformity in water distribution.

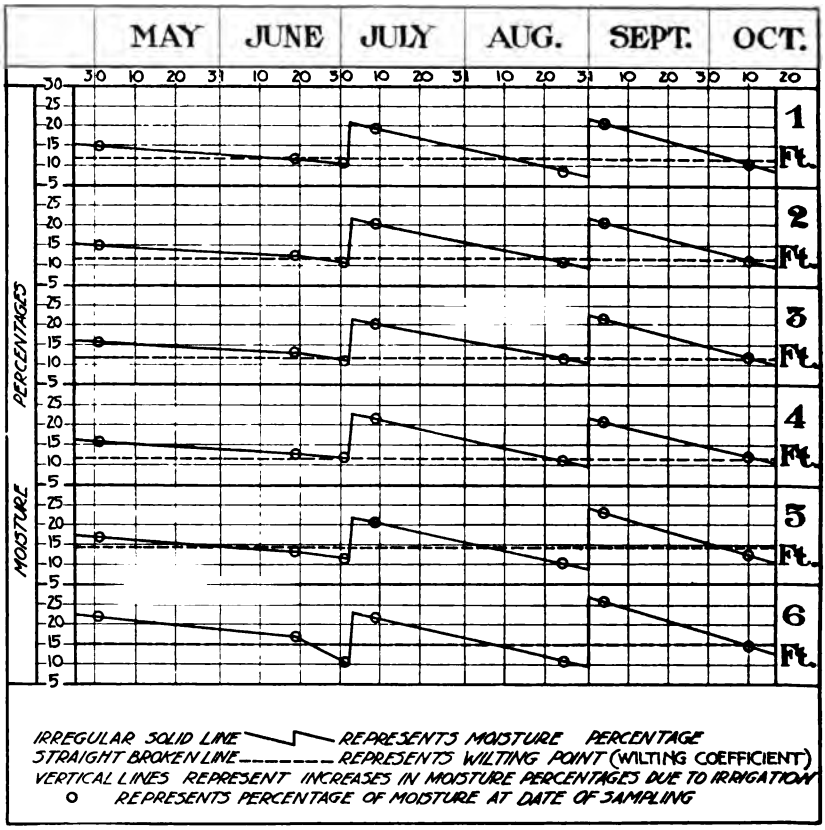


Fig. 15.—Diagram showing seasonal variation in soil moisture percentage, Hughson alfalfa field, Woodland, 1914.

Beck Field. The soil of this field is classed as Yolo loam. Soil moisture determinations were made from nine borings at each cutting and before and after each irrigation in 1914. Results, as platted in figure 16, indicate a very uniform decrease in moisture content of the soil from the beginning of the growing season until the first irrigation after the third cutting. The moisture present was above the wilting point throughout the upper six feet at the time of the first cutting, but was reduced to or below the wilting point by the second cutting,

and went below the wilting point in the upper four feet by the third cutting, although with appreciably no change at the fifth and sixth foot in depth. At the first irrigation a depth of 11.56 inches of water was applied, of which 5.04 acre-inches per acre, or 43 per cent, was retained in the upper six feet, one-fourth of this remaining in the surface foot. At the second irrigation a depth of 7.48 inches was applied, of which 3.34 acre-inches per acre, or 45 per cent, was retained in the upper six feet, with one-third of this remaining in the surface foot.

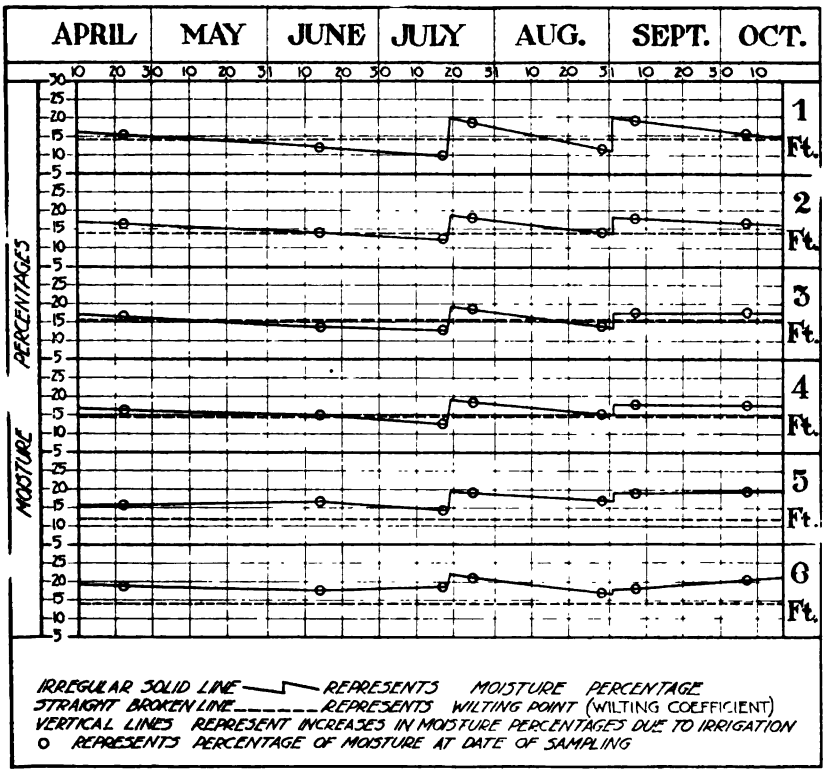


Fig. 16.—Diagram showing seasonal variation in soil moisture percentage, Beck alfalfa field, Woodland, 1914.

Griffes North Field. The soil in this field is classed as a silt loam. The field was irrigated twice in 1914 with approximately equal applications averaging 11.76 inches in depth. Moisture determinations were made from 18 holes before and after each irrigation and at each cutting except the fifth, when 12 holes were bored. At the first irrigation the upper six feet retained an average of 56 per cent of the amount applied, with relatively slight differences in the amount retained in each foot.

At the second irrigation 47 per cent of the quantity applied was retained, with the heaviest increase in the surface foot section. After the second irrigation the moisture decreased with the depth and indicated that less water went below six feet at the second irrigation than at the first. On the two plats into which the Griffes north field was divided, the north plat invariably showed a higher moisture content and produced a larger tonnage of hay. Taking the Griffes north field as a

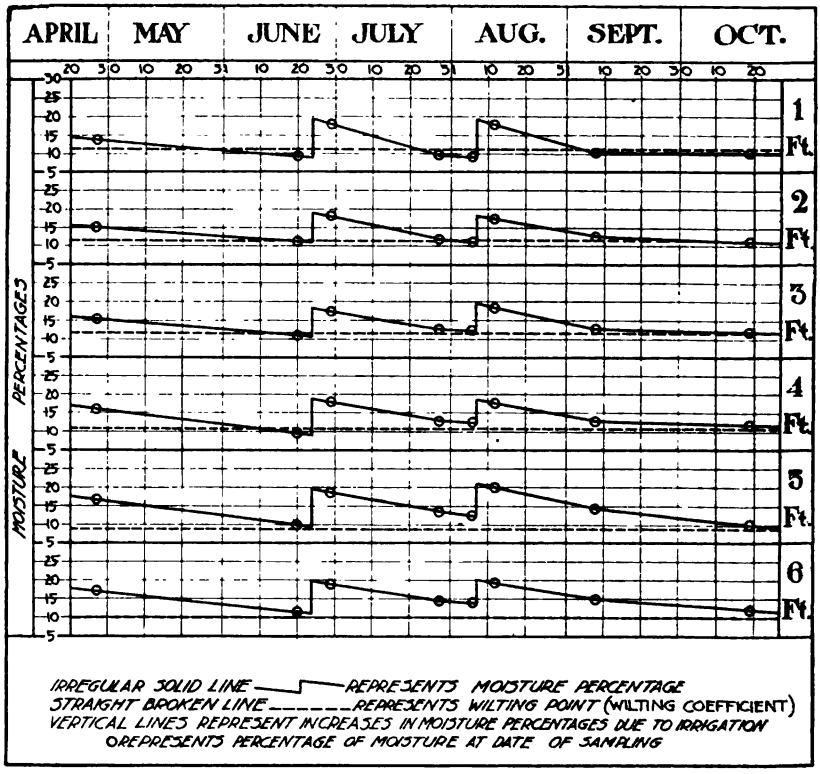


Fig. 17.—Diagram showing seasonal variation in soil moisture percentage, Griffes north field, Woodland, 1914.

whole the results in 1914, as platted in figure 17, indicate an abrupt decrease of the moisture content of the soil between cuttings and an abrupt increase caused by irrigation, the differences being more marked than in the case of any other fields in the Woodland area. This is accounted for by the coarse texture of the soil. While the upper strata of soil, in which the moisture was found to be below the wilting point just prior to irrigations, were amply replenished by watering, the determinations indicate that the lower stratum received more than necessary, showing that lighter irrigations would have proven more economical.

Guile Field. (Fig. 18.) The soil of this field is classed as Yolo clay loam. Moisture determinations were made from six borings before and after the two irrigations given in 1914, from three borings at the first cutting and six borings each at the fourth cutting and at the end of the season. At the first irrigation a depth of 7.28 inches was applied, of which 4.03 inches, or approximately 55 per cent, remained in the upper six feet, nearly one-half of this remaining in the surface foot. At the second irrigation a depth of 5.94 inches was given, of which

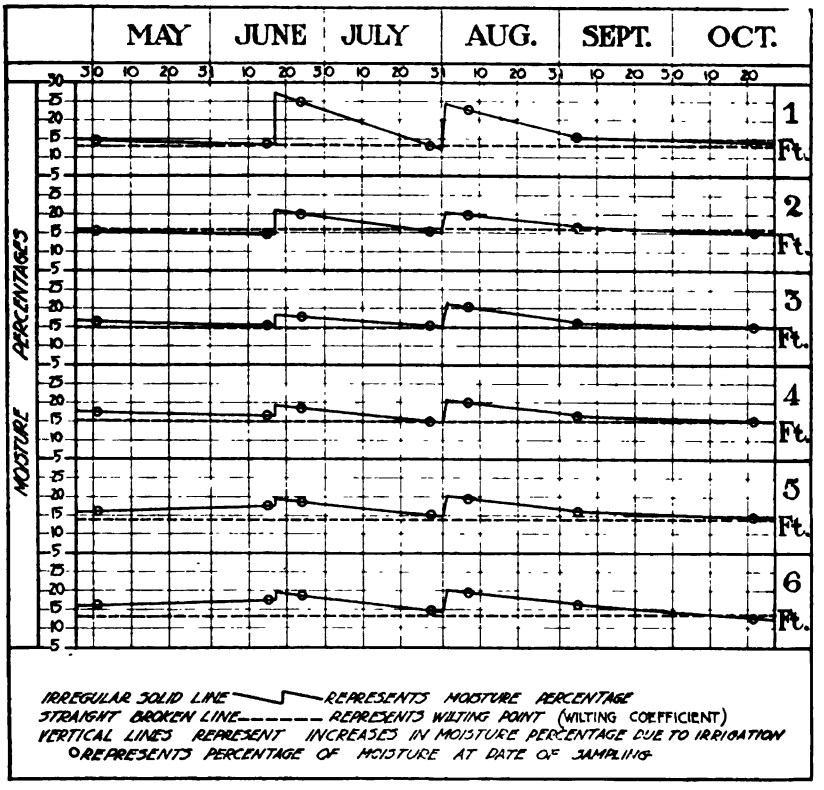


Fig. 18.—Diagram showing seasonal variation in soil moisture percentage, Guile alfalfa field, Woodland, 1914.

nearly 91 per cent was accounted for in the upper six feet, about one-third remaining in the surface foot. The relatively small quantities of water found below the surface foot or two confirmed field observations of the resistance offered by the soil of this field to the penetration of irrigation water. At the time of the first cutting the moisture content of the soil was so low, as shown by the diagram, that nowhere in the upper six feet was it much, if any, above the wilting point. And the same condition was approximated at the time of each subsequent cutting. Owing to the impermeability of this soil, heavy irrigations

were shown not to be practical. Perhaps no field studied in the Woodland area was found to be so dependent upon timely irrigation as was this one.

Jackson-Woodard Field. (Fig. 19.) The soil of this field is classed as Yolo clay loam. In 1913 moisture determinations on the north plat were made from six borings before and after the third irrigation, from ten before and after the fourth, from four before and after the fifth, and on the south plat from ten borings before and after each of the third, fourth, and fifth irrigations. The applications of water at the

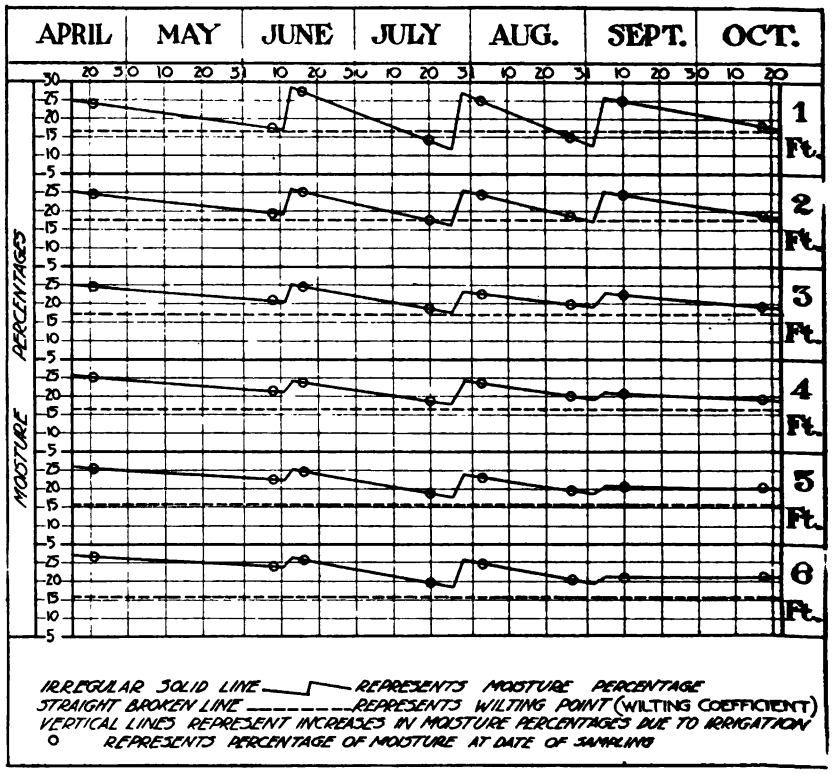


Fig. 19.—Diagram showing seasonal variation in soil moisture percentage, Jackson-Woodard alfalfa field, Woodland, 1914.

three irrigations were nearly equal, averaging 5.6 inches in depth on the north plat and 5.4 inches in depth on the south plat. The average depth of penetration of irrigation water on the north plat was found to be about four feet after the third irrigation and only two feet after the fourth and fifth irrigations, whereas in the south plat percolation extended to or exceeded six feet in each case. On the north plat the increases by irrigation were always small; on the south plat, however, 39 per cent was retained in the upper six feet at the third irrigation,

nearly 26 per cent at the fourth irrigation, and over 41 per cent at the fifth irrigation, the largest increases occurring in the surface two feet. In 1914 moisture determinations were made from six borings before and after each irrigation in each plat and at each cutting. The same differences in penetration of irrigation water found in 1913 were noted again. In addition to conserving a larger proportion of each irrigation, the south plat generally was found to contain a higher percentage of moisture than the north plat, especially in 1914, and the south plat in both years gave correspondingly larger yields of hay. As compared with the other fields in the Woodland area, there was a much higher percentage of moisture in the Jackson-Woodard field at the time of the first and second cuttings in 1914, with the average also remaining higher throughout the season. Prior to each irrigation, and more noticeably as the season advanced, the upper 12 to 18 inches of soil was found to be deficient in moisture, while the remainder of the six-foot section retained a uniformly fair moisture content. In both 1913 and 1914 the greatest increase in moisture resulting from irrigation took place at the lower ends of the checks, which varied in length from 340 feet to 575 feet. In 1914, for instance, when borings were made in three places in each check studied, the mean increase, expressed in acre-inches per acre, due to irrigation for the three irrigations was, respectively, 1.51 at the upper end, 2.44 at the middle, and 3.67 at the lower end in the north plat, and 3.44 at the upper end, 3.92 at the middle, and 4.74 at the lower end in the south plat. In other words, the soil did not absorb the water as rapidly as it was applied, and the result was an excess at the lower ends, where it penetrated in due time into the soil.

TABLE No. 13.

Summary of Results of Alfalfa Duty of Water Investigations, Woodland Area, 1913.

Name	Soil type	Area, acres	Number of irrigations	Total depth water applied, feet	Number of cuttings	Total yield, tons per acre
Geo. W. Hughson	Silt loam	19.54	3	4.40	5	9.12
H. J. N. Rasmussen	Silt loam	15.94	3	4.22	4	5.52
Sylvester Lawson	Silt loam	25.63	4	2.38	5	5.91
Wm. Exley	Silty clay loam	23.20	4	2.81	4	4.77
R. E. Fisher	Silty clay loam	37.71	3	1.30	5	3.46
Frank Hermle	Silt loam	23.88	3	3.12	5	6.69
Geo. O. Griffes (south field)	Fine sandy loam	16.65	4	3.07	5	7.49
Geo. O. Griffes (north field)	Silt loam	48.80	3	3.26	3	[1]2.55
D. B. Guile	Silty clay loam	28.21	4	2.14	4	4.42
Jackson & Woodard (north plat)	Clay loam	10.26	6	3.89	5	7.68
Jackson & Woodard (south plat)	Clay loam	9.49	6	3.08	5	8.51
Mrs. Nettie Hadsall	Silty clay loam	35.76	2	2.11	4	4.17
Averages				2.94		5.86
Averages, excluding young alfalfa				2.91		6.16

[1]Young alfalfa.

NOTE.—Rainfall November 1, 1912, to October 31, 1913, 0.61 foot

TABLE No. 14.

Summary of Results of Alfalfa Duty of Water Investigations, Woodland Area, 1914.

Name	Soil type	Area, acres	Number of irrigations	Total depth water applied, feet	Number of cuttings	Total yield, tons per acre
Wm. Gould	Silty clay loam	19.95	0	0.00	5	4.05
Geo. W. Hughson	Silt loam	19.54	2	2.91	5	6.96
H. J. N. Rasmussen	Silt loam	10.23	0	0.00	3	3.61
John Beck[1]	Yolo loam	23.20	2	1.59	5	7.28
R. E. Fisher (east plat)	Silty clay loam	16.21	0	0.00	3	3.33
R. E. Fisher (west plat)	Silty clay loam	21.50	3	2.08	5	4.92
Geo. O. Griffes (south field, east plat)	Fine sandy loam	5.48	1	1.41	5	6.12
Geo. O. Griffes (south field, west plat)	Fine sandy loam	11.17	1	1.00	5	5.56
Geo. O. Griffes (north field, north plat)	Silt loam	24.40	2	1.96	5	7.81
Geo. O. Griffes (north field, south plat)	Silt loam	24.40	2	1.96	5	7.40
D. B. Gulle	Clay loam	28.21	2	1.14	4	4.26
Jackson & Woodard (north plat)	Clay loam	10.26	3	2.14	5	8.07
Jackson & Woodard (south plat)	Clay loam	9.49	3	1.88	5	9.11
Averages for irrigated fields				1.80		6.75

[1]The Exley tract in 1913.

NOTE.—Rainfall November 1, 1913, to October 31, 1914, 2.45 feet.

DESCRIPTIONS OF FIELDS IN THE WOODLAND AREA AND COMMENTS ON IRRIGATION CONDITIONS AND PRACTICES.

Wm. Gould Field. Seeded in 1910. Stand of alfalfa rather thin, with bare spots of considerable area. Checks 866 feet by 50 feet. Preparation of land good. Observations made on this tract only in 1914; it was not irrigated in 1914, owing to the low market price of alfalfa hay, but data were secured on yields in order to afford comparison with irrigated fields.

Geo. W. Hughson Field. Seeded in 1903. Stand of alfalfa good. Yields heavily but is being thinned out by gophers and by difficulty of getting water to lower ends of some checks. Checks 1,270 feet by 82 feet, with grade averaging 4.3 inches in 100 feet. Preparation of land fair, but checks much too long for porous silt-loam soil, for they require excessive applications of water at upper ends in order to wet lower ends, resulting in great waste of water. Small check-gates also contribute to this end. First three crops irrigated in 1913 and third and fifth in 1914, heads used varying from 12 to 22 cubic feet per second, divided among three to five checks. Second irrigation in 1914 covered only part of field. Difference in crop yields between 1913 and 1914 is attributable to lateness of first irrigation in 1914 and insufficiency of moisture later on.

H. J. N. Rasmussen Field. Seeded in 1910. Stand of alfalfa fair. Checks vary in length from 165 to 720 feet and in width from 40 to 90 feet. Grade averages 3.4 inches in 100 feet. Field divided into three sets of checks and general preparation good. Irrigating heads used in 1913, when the first three crops were irrigated, ranged from 14 to 22 cubic feet per second. In 1914, owing to low prices received for alfalfa hay, field not irrigated. Yield in 1913 reduced by grasshoppers.

Sylvester Lawson Field. Seeded in 1911. Stand very good over most of field, but there are several gravel streaks where poor. Checks vary in length from 740 to 1,080 feet and average 57 feet wide. Grade fairly uniform, averaging 4.6 inches in 100 feet. Land generally well prepared for irrigation. Observations made on this tract only in 1913, when heads used ranged from six to seventeen cubic feet per

second, only third crop being unirrigated. Soil moisture determinations at third irrigation indicated very unequal distribution of moisture. Two of crops damaged by grasshoppers.

Wm. Exley–John Beck Field. Seeded in 1906. Stand of alfalfa fair. Checks range from 375 to 1,290 feet in length, but width fairly uniform, averaging 73 feet. Grades range from zero to eight inches in 100 feet, averaging 3.1 inches. Preparation for irrigation fair. First, second, fourth, and fifth crops irrigated in 1913, with heads of nine to 14 cubic feet per second, and last two crops irrigated in 1914 with heads of 15 to 20 cubic feet per second, turned into two or three checks at a time. The great difference between yields of hay from this field in the two years studied due to ravages of grasshoppers, inability to cut the last crop because of rain, and inability to secure water when most needed in 1913, none of which conditions obtained in 1914.

R. E. Fisher Field. Seeded in 1907. This tract treated as single unit in 1913, but was divided into two plats in 1914. Stand generally good, but thinning out. Checks in east plat 320 to 630 feet long, in the west plat 700 feet long, and all average 58 feet wide, average grade being 1.9 inches in 100 feet. Field well prepared for irrigation, but ditches, originally made to take water from canal system, are too large for small heads, averaging 2.74 cubic feet per second in 1913 and 3.15 in 1914, secured from the pumping plant which now supplies the tract; checks also are too wide. Last three crops irrigated each year, but in 1914 only west plat was irrigated. Lower yield of hay in 1913 was due to failure to irrigate until after second cutting and to damage by grasshoppers.

Frank Hermle Field. Seeded in 1910. Stand excellent. Checks 630 to 640 feet long, average 65 feet in width, with average grade of 1.4 inches in 100 feet. Land well prepared for irrigation. First three crops irrigated in 1913, which was the only season in which observations were made, heads ranging from 13 to 19 cubic feet per second.

Geo. O. Griffes South Field. Seeded in 1912. This field comprises two distinct parts and in 1914 these were treated as separate units. Stand excellent. In the east plat checks are 800 feet long and in the west plat average 575 feet, all being 57 feet wide, with grade averaging 2.1 and 3.5 inches per 100 feet in east and west plats, respectively. Field well prepared for irrigation. In 1913 all crops except the third were irrigated, with heads of 11 to 15 cubic feet per second, and at the single irrigation between the third and fourth cuttings in 1914 the head averaged 20 cubic feet per second. Often the entire head was turned into a single check. Lower yields in 1914 were obviously due to the fact that only the fourth crop was irrigated, whereas all of the last three crops needed water.

Geo. O. Griffes North Field. Seeded in 1913. This field was divided into two plats for observational work in 1914. Stand of alfalfa one of the best in the area and field one of the most carefully prepared. Checks are all 810 feet long and 54 feet wide, with average grade of 1.4 inches in 100 feet in north plat and of 1.8 inches in south plat. All three crops were irrigated in 1913 with heads of 11 to 15 cubic feet per second, and in 1914 the third and fourth crops were irrigated with heads of 15 to 21 cubic feet per second, usually divided between two checks. The yields in the two seasons can not be compared owing to the fact that the alfalfa was in its first year in 1913.

D. B. Guile Field. Seeded in 1910. Stand of alfalfa fair. Checks average 1,275 feet in length, but vary in width from 45 to 120 feet, with average grade of 1.8 inches in 100 feet. Preparation for irrigation only fair. All four crops were irrigated in 1913 and last two in 1914, the heads of water averaging 12 cubic feet per second and usually were turned into single checks. It should be noted that, although only about one-half as much water was applied in 1914 as in 1913, the yield of hay was about the same in both years. This was accounted for by heavier rainfall and more timely irrigations in 1914.

Jackson-Woodard Field. Seeded in 1912. This field was treated as two units in 1913 and 1914. Stand of alfalfa excellent. In the north plat checks were 400 to 575 feet long, with grade averaging 2.2 inches in 100 feet, and in the south plat 340 to 520 feet, with average grade of 3.2 inches. All checks were about 40 feet wide. The checking system in this field was designed for a pumping plant and the general preparation was good. All crops were irrigated in 1913, including an irrigation after the fifth cutting, but in 1914 only the last three crops were irrigated. The pumping plant gave an average irrigating head of 3.78 cubic feet per second in 1913 and of 4.37 in 1914, in both cases being turned into one check at a time.

Mrs. Nettie Hadsall Field. Seeded in 1909. Stand only fair. Checks 970 to 1,105 feet long and from 45 to 60 feet wide, with average grade of 2.9 inches in 100 feet. Field generally well prepared for irrigation. Observations made only in 1913, in which year first and second crops were irrigated with heads of 13 to 16 cubic feet per second. This field is located under the Adams Canal and no water was available after early summer, whereas the tracts supplied by Moore Canal had a small amount for a much longer time, and this deficiency resulted in a low yield of hay.

Dixon Area.

Dixon is located in Solano County in the southwestern portion of Sacramento Valley. The nearest rainfall record is for Davis, eight miles northeast, where the mean is 17.23 inches.[1] At present no canal system serves the Dixon area, all irrigation water being secured by pumping from wells. In most cases the water is applied directly to the land without storage in farm reservoirs, although in the western part of the area several tracts are being irrigated from small pumping plants used in conjunction with storage. Some of the pumping plants are equipped with gas engines, but the majority have electric motors.[2] The soils of the area are mostly clay loams and clays of the Yolo and Capay series.[3]

Of the crops grown under irrigation, alfalfa occupies by far the largest acreage. In 1913 the average yield of six tracts of mature alfalfa was 6.76 tons per acre, distributed among five cuttings of 1.79, 1.61, 1.79, 1.35, and .22 tons per acre, respectively. The sudden drop in the average of the last cutting was due to the fact that the alfalfa on only two of these fields was cut five times, four crops being cut on three fields and three crops on the other.

The number of irrigations between cuttings varied in 1913 from one to four. Owing to the dryness of the season all first crops were irrigated, but in years of heavy rainfall one or even two crops may be grown without irrigation. The water-table was relatively low in 1913, and measurements of the discharges of 11 pumps showed all to be delivering below their rated capacities. Of two eight-inch pumps, the discharges were 29 and 36 per cent, respectively, below rated capacity; of three seven-inch pumps, the discharges were 12, 13, and 27 per cent

[1] Weather Bureau, Annual Summary for 1915.
[2] Underground water conditions are discussed in U. S. Geol. Survey Water Supply Paper 375-A, Ground Water for Irrigation in the Sacramento Valley, California.
[3] U. S. Dept. Agr., Bureau of Soils, Reconnoissance Soil Survey of the Sacramento Valley, California.

below; of two six-inch pumps, 43 and 47 per cent below; and of four five-inch pumps, 54, 58, 66, and 71 per cent below, respectively. The expedient of lowering the pump several feet, which was tried by some owners, usually resulted in an increased flow.

Both square or rectangular and border checks are in use at Dixon, the former usually being made as nearly square and as nearly level as possible. Of the two, border checks probably are the more widely used, but on the heavier soils the square or rectangular checks are considered to give better results because it is possible, with such checks, to keep water standing on the land longer than with border checks, thus facilitating penetration. Square or rectangular checks at Dixon usually are about 100 feet square and border checks vary in length from 75 to 1,750 feet and in width from 30 to 40 feet, with a grade of three to five inches in 100 feet. Check gates are small wood or concrete structures, but often water is admitted to checks through cuts in the ditch banks. Metal dams or tappoons often are used for diverting water into the checks.

Seven typical fields were included in the investigation at Dixon in 1913 (Fig. 20), weirs generally being used for measuring the applications. Underground movement of irrigation water applied was traced only on the Wright field, and owing to difficulty in penetrating the heavy soil with a soil auger moisture determinations are available for the upper six feet of soil from only ten borings before and after the fourth irrigation, from four before and after the fifth, and from nine before and after the sixth. The mean moisture content of the upper six feet of soil over the whole tract was safely above the wilting point throughout the period of these determinations, although in many single instances the percentage fell below the wilting point prior to irrigations. This good moisture condition is attributed to the frequent light irrigations given, and the effect is well

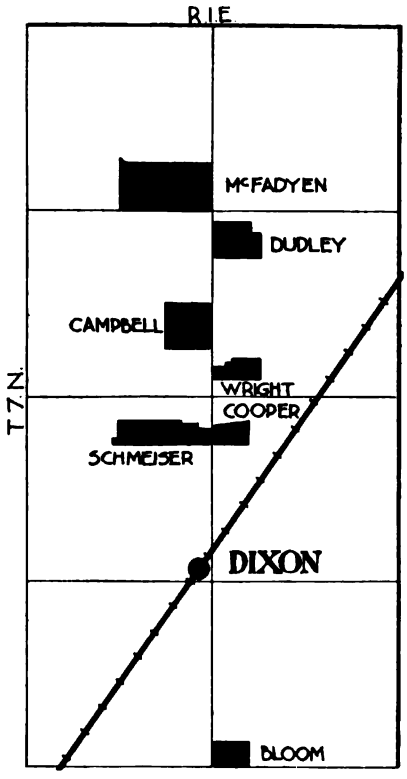


Fig. 20.—Map of Dixon area showing location of alfalfa fields under investigation, 1913.

shown in the high yields of hay secured—9.97 tons per acre. The highest percentage of moisture was found before and after the fifth irrigation.

The distribution of the irrigation water applied throughout the upper six feet of soil at the fourth irrigation, when the moisture determinations were commenced, was very uniform, 49 per cent of the 5.06 inches in depth applied being accounted for. At the fifth irrigation, when a depth of 6.06 inches was given, only 31 per cent remained in the upper six feet of soil, over one-third of this remaining in the surface foot. The moisture found in the soil after the sixth irrigation decreased perceptibly with the depth, indicating that little passed below six feet, and that the principal part of the moisture not accounted for was utilized by the crop, or evaporated from the surface.

In addition to the borings made to a full depth of six feet, four additional borings before and after the fourth irrigation, six before and after the fifth, and three before and after the sixth irrigation were stopped by failure of the irrigation water to soften the hard soil to the full six feet. This again illustrated the desirability of having irrigations on this field sufficiently frequent to keep the soil moist constantly throughout the rooting zone of the plants.

TABLE No. 15.

Summary of Results of Alfalfa Duty of Water Investigations, Dixon Area, 1913.

Name	Soil type	Area, acres	Number of irrigations	Total depth water applied feet	Number of cuttings	Total yield, tons per acre
J. R. Bloom	Clay loam	10.36	6	2.82	3	5.22
Mrs. Letitia Cooper	Clay loam	10.01	5	2.27	4	6.92
C. E. Schmeiser	Clay loam	36.20	8	3.06	4	5.61
D. W. Wright	Clay loam	12.10	8	3.15	4	9.97
M. D. Campbell	Clay loam	36.74	12	2.79	3	[1]1.72
E. D. Dudley	Silt loam	26.64	15	2.93	5	7.12
Harry McFadyen	Clay loam	74.12	15	3.43	5	5.72
Averages				2.92		6.04
Averages, excluding young alfalfa				2.94		6.76

[1]Young alfalfa.

NOTE.—Rainfall November 1, 1912, to October 31, 1913, 0.61 foot.

DESCRIPTIONS OF FIELDS IN DIXON AREA, AND COMMENTS ON IRRIGATION CONDITIONS AND PRACTICES.

J. R. Bloom Field. Seeded in 1890. Stand of alfalfa, which is one of the oldest in the area, still very good. Checks average 180 feet by 100 feet. Land generally is well prepared. First crop was irrigated once, second crop twice, and third crop three times, with head averaging 2.33 cubic feet per second. The relatively low yield of hay is attributable to lateness of beginning irrigation and to considerable damage done by alfalfa caterpillars (*Eurymus eurytheme*).

Mrs. Letitia Cooper Field. Seeded in 1904. Stand generally good. Checks roughly rectangular, from 55 to 195 feet long and averaging 52 feet wide. Checks mostly nearly level, but the longer ones have a grade of several inches in 100 feet.

General preparation for irrigation is good. Each crop was irrigated once with a head of 1.13 cubic feet per second, and a partial irrigation given after the fourth cutting. Water is purchased from a neighbor and the relatively low use probably is due to the fact that it was available only for a small part of the time.

C. E. Schmeiser Field. Seeded in 1907. Stand fair. Checks rectangular, about 110 feet long and 100 feet wide, and as a rule are mostly nearly level. Preparation for irrigation good. Each crop was irrigated twice with a head of 1.06 cubic feet per second.

D. W. Wright Field. Seeded in 1906. Stand very good. Checks rectangular, about 100 feet long and averaging 92 feet wide, and mostly nearly level. Land fairly well prepared for irrigation. First crop was irrigated once and each succeeding crop twice and extra irrigation was given after the fourth cutting. Average head of water .72 cubic foot per second.

M. D. Campbell Field. Seeded in 1912. Stand good. Field in border checks, 200 to 1,750 feet long and averaging 33 feet wide with average grade of three and one-half inches in 100 feet. General preparation for irrigation good. Each crop, including the pastured fourth crop, was irrigated three times with a head averaging 2.35 cubic feet per second.

E. D. Dudley Field. Seeded in 1912. Stand excellent. Border-check system followed, checks ranging from 85 to 570 feet long and averaging about 38 feet wide, with average grade of about six inches in 100 feet. Land, for the most part, is well prepared for irrigation. First crop was irrigated twice, second, third, and fourth crops three times each, and the last crop four times, with an average head of 1.94 cubic feet per second.

Harry McFadyen Field. Seeded in 1911. Stand of alfalfa good. Border checks, 60 to 940 feet long, average of 30 feet wide, with average grade of 3.6 inches in 100 feet. Land well prepared for irrigation. Each crop was irrigated three times with head averaging 2.44 cubic feet per second.

DISCUSSION OF RESULTS.

Comparison of Duty of Water and Yields of Alfalfa on 54 Sacramento Valley Farms with Results of Experiments at Davis.

As stated at the beginning of this bulletin, the purpose of the investigations herein reported was to obtain data that, taken in connection with the results of experiments in the duty of water for alfalfa at Davis, would give a basis for conclusions regarding the most satisfactory duty for this crop throughout Sacramento Valley. When a comparison is undertaken between the results of the investigations on the 54 Sacramento Valley farms studied in 1913 and 1914 and the results obtained at Davis from 1910 to 1915, it at once becomes clear that there is a wide variation, and that the results are not comparable unless full account is taken of the extreme differences in the conditions met. When the differences are analyzed, however, and the comparison is made between like or similar conditions, the results are not far apart. They are, in fact, sufficiently near agreement to establish the Davis results as applicable, in general, to the entire valley.

At Davis the amounts of water used were strictly under control, and, with the exception of the plat receiving a depth of 60 inches, single irrigations were, as a rule, not greater than the soil would retain, the soil

moisture determinations before and after irrigation showing that an average of 76.4 per cent of the water applied to plats which were given a depth of six inches in one irrigation was retained in the upper six feet of soil and that the plats given seven and one-half, nine, and 12 inches irrigation, making an average of nine and one-half inches per application, retained an average of 60.6 per cent in the upper six feet of soil and 97.7 per cent in the upper 12 feet. The soil of the experimental irrigation tract at Davis is chiefly a fine silt loam, relatively uniform, with no impervious stratum, and with the ground water level below the normal feeding zone of the plant roots. The upper two feet is very uniform, but the third to eighth feet are of fine, sandy loam, pocketed at irregular intervals with coarse sand or clay loam. While at Gridley the surface soil of the fields under observation in 1913 does not vary greatly from the soil at Davis, most of it is underlain with hardpan, and all of it contained free ground water at six feet or less from the surface. At Los Molinos, while the soil of some of the fields is comparable with that at Davis, being of silty or sandy loam and of relatively uniform depth for at least 12 feet from the surface, some fields have more clay and some are more gravelly than those at Davis. The normal rainfall at Red Bluff, which is the nearest point of observation to Los Molinos, is approximately nine inches greater than at Davis, and in the years 1913 and 1914 it was more than six inches above the average at Davis for the six years covered by the experiments there. An entirely different type of soil is found at Orland, all but one of the fields investigated having been made up largely of gravel. Here, also, water conditions differ considerably from those at Davis, a shortage of water in the late season in 1913 having made it necessary to eliminate one irrigation.

A very wide departure in soil type is encountered at Willows and, as indicated by the summaries of use on fields under investigation there, it was impossible to get enough water into the soil to satisfy the needs of the crop. While the soils at Woodland are generally comparable with those at Davis, paying for irrigation water on a quantity basis rather than on an acreage basis, as at Gridley, Los Molinos, Orland, and Willows, altered the Woodland practice materially. During the season of 1913 at Woodland, following a winter of low rainfall, the usual practice was to give at least three irrigations, and some farms received water six times, alfalfa bringing good prices that year and water therefore being applied plentifully. In 1914, however, following a winter of more than normal rainfall, and when the price of alfalfa had dropped to nearly one-third the figure obtainable in 1913, no irrigators watered more than three times and as a rule only two, with many not watering at all. Observations were made at Dixon during 1913 only. Water used there is obtained from pumping plants and use generally represents

what the various irrigators consider to be necessary. While in this regard conditions at Dixon are similar to those which governed during the experiments at Davis, at Dixon the soil is considerably heavier than at Davis, and takes water much less freely.

Gridley. Analyzing the results obtained at Gridley, it was found that a maximum yield of 9.38 tons was obtained from a field which received a total annual depth of irrigation water of 31.6 inches, but that the next nearest yield was only 7.28 tons per acre obtained on a field which received 34 inches of water for the season. Eight out of the fourteen fields studied at Gridley received greater annual depths of irrigation water than 34 inches, but on three of these the yield fell below five tons, on four below six tons per acre, and on seven below seven tons. In other words, after eliminating the single field that had the excessive yield of 9.38 tons per acre, it was found that the point beyond which it did not pay to add to the depths applied corresponds substantially with the points established in the Davis experiments, namely, between 30 and 36 inches. The seasonal rainfall at Gridley preceding the heaviest of these yields was 13.9 inches.

Los Molinos. Analyzing the results obtained at Los Molinos for the seasons 1913 and 1914, it is found that a maximum yield of 8.31 tons per acre was obtained with a total annual application of 47.4 inches, following an average rainfall for the two seasons of approximately 24.4 inches. To what extent, if at all, excessive use here reduced yields by soil leaching can only be conjectured. Seven of the 11 fields under observation received more irrigation water than the field of maximum yield, the maximum application being 84 acre-inches per acre. Of these seven fields, however, one yielded less than four and one-half tons per acre, four below six tons per acre, and six below seven tons per acre. At Los Molinos it is to be noted that both the maximum and the majority of applications were considerably in excess of the applications at Davis, but as pointed out in the discussion of soil moisture determinations in this area, the soils of the Los Molinos fields are highly permeable and the use of water was wasteful. Studies of the underground distribution of the irrigation water applied showed that beyond a doubt large quantities passed below a depth of six feet, single applications amounting, in numerous cases, to between 20 and 30 inches.

Orland. Averages for eight fields at Orland, where the soil is prevailingly gravelly, gave a maximum of 6.77 tons per acre with a total annual application of 24.6 inches after an average seasonal rainfall of 19.2 inches. The maximum yield at Orland was obtained on the field that received the least water, the yield from two of the seven remaining fields falling below five tons, and that from five falling below six tons. Of the whole eight fields water was applied in excess of 80 inches on

two fields, in excess of 55 inches on three fields, and in excess of 45 inches on five fields.

Willows. With complete results available for only one year and from only three fields at Willows, but with these results verified by special studies in 1915, it is evident that the results are in no way comparable with the results at Davis, this being due to the "tightness" of the soil of the Willows fields and the impossibility of getting irrigation water into it in amounts sufficient to satisfy the plants. A maximum yield of only 5.39 tons was obtained at Willows with an application of 23.6 inches in addition to the seasonal rainfall of approximately 28.7 inches for the preceding winter. Results at Willows indicate plainly that the soil-moisture needs of alfalfa, on the soils that hold moisture so tenaciously as do those at Willows, are in excess of the maximum applications found in 1914. Further, it is plain from the special studies in 1915 that to irrigate adequately the silty clay loams and the clay adobes of the Willows area, water must be applied frequently and in small quantities, and at no time following the winter rainfall must the soil be allowed to dry out. The amount of water used on these Tehama clay soils is sure to increase as improvement in their physical condition, due to cropping and cultivation, makes them more pervious to water.

Woodland. Averages for the 12 fields at Woodland, for which full records are available, show a maximum yield of 8.81 tons per acre with a use of water of 29.7 inches in addition to an average seasonal rainfall of 18.3 inches. Three fields, which received depths of 23.5, 33.1, and 43.7 inches, gave respective yields of 7.60, 7.87, and 8.04 tons per acre. Taking seven fields for which the yields were most nearly equal, the range of variation being slightly over two tons and the average yield being 6.93 tons per acre, the average use was found to be a depth of 30.7 inches. Thus, at Woodland it is found also that the usual maximum use, taking an average of one wet and one dry season, does not depart widely from that found most satisfactory at Davis; also that the maximum average yield for one field during the two years of record was obtained with slightly less than 30 inches.

Dixon. Here the largest yield in the single year of observation was 9.97 tons per acre with a total depth of irrigation of 37.7 inches, in addition to a seasonal rainfall of 7.31 inches. The average use for six fields, from which complete records are available, was 35.3 inches, or again in close agreement with the Davis experiments.

The allowance necessary to be made for difference in local soil conditions and irrigation practice is, it is believed, fully established by the comparisons made above. In general, as already indicated, the statement is justified that the six-year record for Davis is applicable

throughout the valley with the exception of on the very open soils such as those around Orland, and also with the exception of the silty clays and clay adobes found in these investigations in the neighborhood of Willows, but also existing elsewhere in considerable areas. The average for Willows indicates, as already pointed out, that total irrigations of less than 24 inches per season are insufficient for satisfactory yields, while the results at Orland indicate that applications averaging in excess of 48 inches per year, while sometimes difficult to overcome on the very gravelly soils, do not give corresponding increases in tonnage. The average use at Woodland, which was below that at either Dixon or Gridley, was plainly a result of the payment for irrigation water on a quantity rather than on a flat acreage basis. Finally, the average at Gridley illustrates what may be expected on the open loam soils underlaid with hardpan or ground water.

TABLE No. 16.

Summary of Results of Alfalfa Duty of Water Measurements on 54 Farms in Sacramento Valley, 1913 and 1914.

Name of area	Average rainfall, inches	Number of fields included	Areas covered by observations	Years	Average total depths of water applied, feet	Average total yields, tons per acre
Gridley	[1]22.24	14	284.22	1913	3.31	6.19
Los Molinos	[2]26.11	12	130.40	1913-14	5.15	6.01
Orland	19.23	7	214.52	1913-14	4.66	6.26
Willows	16.55	8	27.71	1914	1.83	4.82
Woodland	[3]17.23	12	295.07	1913-14	2.33	6.45
Dixon	[3]17.23	6	207.17	1913	2.94	6.76
Totals and averages	19.76	54	1,159.09		3.37	6.08

[1]Biggs record.
[2]Red Bluff record.
[3]Davis record.

Quantities of Water to Apply to Sacramento Valley Alfalfa Fields at Single Irrigations as Determined by the Capacity of the Different Soils to Retain Water.

Investigations of the gross and net duty of water made in the western states during the past two decades have demonstrated fully the need for carrying duty of water studies further than measuring the quantities of water applied. Therefore, in recent years, investigators have turned their attention to more or less precise methods of determining water requirements of crops under the various western soil and climatic conditions. The experiments on the duty of water for alfalfa conducted at Davis from 1910 to 1915 were intended to be as nearly as possible an application of these more or less precise methods to typical field conditions. When conducting the more general studies on typical farms throughout the Sacramento Valley, however, it was not possible, as already pointed out, to duplicate fully the methods followed at Davis.

Nevertheless, by making careful observations of the underground distribution of the irrigation water applied, a knowledge of what became of the irrigation water was substituted for a method of control that limited the applications to particular definite quantities.

At the outset of the investigations, one of the important practical questions presented was, how much irrigation water applied at one time, and added to that already present in the soil at the time of irrigation, would the various soils of Sacramento Valley retain? While no particular effort was made in the investigations to ascertain how much irrigation water the various soils encountered would hold during the actual process of irrigation[1], it was desired to ascertain how much would be retained after any surplus should pass on through the soil; or, in other words, how much of the water applied would be retained against gravity. As the amount retained would depend very largely upon the size of the soil particles, it was deemed best to have physical analyses made of the soil from a number of the fields under observation This was done by the division of Soil Technology of the college of agriculture of the University of California. Further: As the quantity of water soils will absorb and the rapidity with which it is absorbed depend quite largely on the compactness of the soil; and, also, in order to be able to determine what portion of the water applied in irrigation was retained by the soil, it was necessary to ascertain the volume weight of the soils "in place." This was done partly by standard laboratory methods, but chiefly by a special field method devised in the course of the investigations, and found to conform within satisfactory limits to other methods commonly used by investigators in more precise experiments.[2]

Reference to the amount of irrigation water that was retained by the soils of the various fields for which soil moisture determinations are available has been made in connection with the results obtained in the various areas. As shown there, the principal work in tracing the underground movement of the irrigation water applied was done on 15 fields—the Huartson and Williams fields at Gridley; the Wigno, Bundy, Hofhenke, and Geer fields at Los Molinos; the O'Hair field at Orland; the Purdy and Tuttle fields at Willows; the Griffes, Beck, Hughson, Guile, and Jackson-Woodard fields at Woodland; and the Wright field at Dixon. Results obtained in 1915 on the special experimental tract northeast of Willows are comparable with results on the 15 fields. The following summary arranges these fields in accordance with a general

[1]This was, however, indirectly ascertained through "pore space" determinations.

[2]The method followed consisted in weighing all of the soil taken from holes carefully bored with a two-inch posthole type soil auger and then ascertaining the volume of this soil as it was "in place" by the use of a thin rubber tube inserted in the hole and filled with a known quantity of water. This method was "checked" against the laboratory method by use of the Bowman soil compactor, the iron cylinder, and the paraffin methods as applied to soils in place, in a series of experiments conducted by Mr. O. W. Israelsen of this investigation and Professor Charles F. Shaw of the division of Soil Technology of the department of agriculture of the University of California.

soil classification and presents the essential data with reference to the amount of water retained in the upper six feet of soil on each field. With the possible exception of the Guile field at Woodland and the fields at Willows, the soil sampling indicated that the full capacity of the soil to retain water, assuming sufficient drainage to carry off the free water, was satisfied.

TABLE No. 17.

Summary of Number of Irrigations per Season, Average Depths of Water Applied at Each Irrigation, and Amounts of Water Retained in Upper Six Feet of Soil for Fifteen Typical Alfalfa Farms in Sacramento Valley, 1913-1914, and by Upper Five Feet of Soil on Willows Experimental Plat, 1915.

Class of soil and name of field	Location	Irrigations per season	Average depths of water applied per irrigation, inches	Water retained by upper 6 feet of soil	
				Acre-inches per acre	Per cent of amount applied
Silt loam soils with fine sandy loam subsoils—					
Wigno	Los Molinos	4	18.25	4.89	26.8
Griffes	Woodland	2	11.78	6.14	52.1
Averages			15.02	5.52	[1]36.8
Silt loam soils—					
Bundy	Los Molinos	4	12.30	4.06	32.5
Beck	Woodland	2	9.52	4.19	44.0
Hofhenke	Los Molinos	4	16.62	4.51	27.1
Averages			12.81	4.24	[1]33.1
Silt loam soils not included in preceding group—					
Hughson	Woodland	2	39.50	8.20	20.7
Huartson	Gridley	4	[2]7.20	4.19	58.1
Williams	Gridley	4	[2]5.88	[2]2.76	46.9
Clay loam soils—					
O'Hair	Orland	3	4.16	2.65	63.7
Geer	Los Molinos	4	19.67	4.50	22.9
Guile	Woodland	2	6.61	4.70	71.1
Jackson-Woodard	Woodland	3	8.04	3.33	41.4
Wright	Dixon	3	[3]5.44	2.31	42.4
Averages			8.78	3.50	[1]39.3
Clay soils—					
Purdy	Willows	4	5.06	1.48	29.2
Tuttle	Willows	4	[4]4.38	2.93	66.9
Averages			4.72	2.20	[1]46.3
Clay soils—					
Plats 3 and 4	Willows Experimental Tract	12	2.00	[5]0.54	27.0
Plats 6 and 7		8	3.00	[5]1.07	35.7
Plats 11 and 12		4	6.00	[5]1.57	26.2
Averages			3.67	1.06	[1]28.9

[1]Averages determined by giving percentages weights proportionate to the amount of water applied.
[2]Sampled only for last three irrigations.
[3]Sampled only for three irrigations.
[4]Sampled only for last two irrigations.
[5]Moisture determinations made to depth of only four feet.
[6]Moisture determinations made to depth of only five feet.

Examination of the above summary brings out the following facts that should be of practical interest to the irrigator:

1. Four times as much water was applied, on the average, to the silt loam soils with fine sandy loam subsoils as it was possible to apply, on the average, to the compact clay soils of the experimental tract at Willows, and more than three times as much as was applied to the clay soils of the Purdy and Tuttle fields at Willows.

2. Only about one-third of the water applied to the silt loam soils, as represented by five fields, was retained for the use of the alfalfa plants in the upper six feet of soil, where the principal root development is located.

3. In the case of none of the 15 fields under observation did the amount of water retained per irrigation in the upper six feet of soil exceed 8.20[1] acre-inches per acre, and in only two cases of the 15 did it exceed six acre-inches.

4. In only two cases out of ten in connection with the clay soils did the water that was absorbed by the upper six feet of soil reach four acre-inches per acre, in only three cases did it exceed three acre-inches per acre, and in four cases it was less than two acre-inches per acre.

5. The average quantities of water retained per acre-foot of soil per irrigation were 0.92 acre-inch for the silt loams with fine sandy subsoils, 0.71 acre-inch for the silt loams without fine sandy loam subsoils, 0.58 acre-inch for the clay loams, and 0.37 acre-inch for the clays, not including the experimental tract at Willows—in every case less than one acre-inch per acre-foot of soil.

6. The maximum average quantities of water retained by the upper six feet of soil per acre-foot per irrigation were 1.02 acre-inches for the silt loams with fine sandy loam subsoils, 0.75[2] acre-inch for the silt loams without fine sandy loam subsoils, 0.78 acre-inch for the clay loams, and 0.49 acre-inch for the clays.

7. Counting only the fields in which the full capacity of the soils to retain water against gravity was satisfied, *i. e.*, all of the fields having loam soils except the Guile field at Woodland, the average water retained per irrigation in the upper six feet of soil was 4.31 acre-inches per acre, or only 32.6 per cent of the average individual applications, and only 0.72 acre-inch per acre-foot of soil.

8. Assuming that in every case the surface foot of soil received at each irrigation sufficient water to satisfy its full capacity to retain water against gravity, it is found from the detailed data at hand that the average for the 18 fields, including the experimental tract at Willows, was 1.23 acre-inches per acre, and that the averages for the different soil types were 1.08 acre-inches per acre for the silt loams, 1.35 acre-inches per acre for the clay loams, and 1.35 acre-inches per acre for the clays. Therefore, in the case of the typical silt loam soils of Sacramento Valley, assuming one irrigation per cutting, single applications of irrigation water exceeding a depth of one to one and one-half inches per foot in depth of soil it is necessary to moisten accomplish no useful purpose; and while the typical clay loams and clays of Sacramento Valley, in their normal condition of moisture, will absorb and hold against gravity as much as one and one-fourth to one and three-fourths inches in depth of irrigation water per foot of soil it is necessary to moisten, that amount of water will not be absorbed by these soils unless it is applied very slowly.[3]

It seems perfectly evident from the figures given above that there is much ground for improvement in the matter of the quantity of water

[1]Clay loam strata at depths varying from eight to ten feet caused partial water logging in overlying soil, hence the figure 8.20 is unusually high. All of the water in this soil was not retained against gravity.

[2]Not counting the field on which 8.20 acre-inches per acre were retained because of abnormal conditions previously referred to.

[3]It is of interest here to note that with the surface foot of soil filled to its capacity to retain water against gravity, the percentages of the pore space of the soil filled were as follows: For the silty loam soils, from 37 to 55 and averaging 45.5; for the clay loam soils, from 51 to 71 and averaging 62.2; for the clay soils, from 57 to 74 and averaging 65.5; and for all of the fields combined, 54.5.

to apply to the alfalfa fields of Sacramento Valley at single irrigations. Had it been feasible to carry the soil moisture determinations to a greater depth than six feet, the extent of the waste resulting from the large single applications would be clearer. The data obtained are, however, sufficient to show clearly that the prevailing practice on Sacramento Valley alfalfa fields is to apply far more water at single irrigations than the more open soils have capacity to retain and than the more compact clay soils absorb under the methods of application followed.

A significant comparison can be made between the amounts of water retained by the soil in the case of the 15 typical Sacramento Valley alfalfa farms and the amounts retained in the case of six of the plats on the experimental tract at Davis, where the applications of water were under definite control. The average depth of water applied per irrigation to these six plats was 7.75 inches and the average quantity retained in the upper six feet of soil in the years 1913, 1914, and 1915 was 4.59 acre-inches per acre, or 66.8 per cent of the amount applied. On some of these plats, however, the borings for soil moisture determinations were made to a depth of 12 feet and it was found that within this depth practically all of the water applied was retained for the benefit of the plants. The average amount of water added by irrigation to the surface foot of soil in the Davis experiments was 1.45 acre-inches per acre. In other words, from the standpoint merely of the capacity of such deep loam soil as that at Davis to retain irrigation water against gravity, and assuming that the lower depths will "take up" as much water as the surface foot, the application once per cutting of one and one-half acre-inches of water per acre-foot of soil it is desired to moisten is not excessive.

Desirable Irrigation "Heads" for Sacramento Valley Alfalfa Fields.

In any investigation of the proper duty of water the size of the irrigation heads used and its relation to the type of soil irrigated, the method of irrigation followed, and the size and slope of the individual areas watered with a single head are always important. Fields may be evenly surfaced and levees perfectly made and proportioned and yet the result still will be excessive waste or inadequate absorption if the stream of water turned into each check is either too large or too small. The discussion as to what became of the water applied on a number of Sacramento Valley alfalfa fields, already presented, showed that where large quantities were applied to the open loam soils at single irrigations much of the water passed below the principal rooting zones of the alfalfa plants, and that the usual practice followed in irrigating the clay soils

failed to accomplish sufficient penetration by the water. The stabilizing of the irrigation heads used in Sacramento Valley, with direct reference to the size of checks and the character of the soil, is obviously one of the very important irrigation problems of the valley. Quite extensive experiments and observations will be necessary for furnishing a satisfactory basis for fully understanding this problem, but the collection of some information bearing on the question was accomplished during the investigations in 1913 and 1914. This information was obtained from twenty-five fields—three at Gridley, two at Los Molinos, five at Orland, two at Willows, nine at Woodland, three at Davis and one at Dixon. Five classes of soil were covered—gravelly loams, three fields; sandy loams, four fields; silt loams, nine fields; clay loams, six fields; and clays, five fields. Observations of the underground distribution of the water applied were made in connection with ten of the fields. The following summary lists the fields according to the soil classification made, with the fields within each group arranged according to the rates of application used expressed in cubic feet per second per acre.

TABLE No. 18.

Summary of Rates of Application of Water to Sacramento Valley Alfalfa Fields at Separate Irrigations, 1913-1915.

Soil type and field	Location	Year	Average length of checks, feet	Average width of checks, feet	Average slope of checks, inches in 100 feet	Number of irrigations represented	Average area of checks, acres	Average head turned into each check, cu. ft. sec.	Average rate of application, cu. ft. per second per acre	Average depth of water applied, feet
Gravelly loams—										
Holland	Orland	1914	150	50	Level	13	0.17	5.2	31.0	0.58
Lawton	Orland	1914	100	100	Level	13	0.23	5.0	22.0	0.74
Spence	Orland	1914	100	100	Level	10	0.23	3.7	16.2	0.56
Average									23.0	
Sandy loams—										
Griffes, south (west plat)	Woodland	1914	575	57	3.5	1	0.75	19.4	25.9	1.00
Griffes, south (east plat)	Woodland	1914	800	57	2.5	1	1.04	20.2	19.4	1.41
Griffes, north	Woodland	1914	810	54	1.0	1	1.00	10.3	10.3	0.96
Griffes, north	Woodland	1914	810	54	1.0	1	1.00	8.2	8.2	1.00
Griffes, north	Woodland	1913	810	54	1.0	1	1.00	8.0	8.0	0.92
Griffes, north	Woodland	1913	810	54	1.0	1	1.00	6.0	6.0	1.11
Griffes, north	Woodland	1913	810	54	1.0	1	1.00	4.8	4.8	1.23
Summers	Gridley	1913	465	56	3.5	4	0.59	2.7	4.6	0.56
Average									10.9	
Silt loams—										
University Farm, west half Field 3	Davis	1915	880	50	3.5	1	1.01	16.0	15.9	0.76
University Farm, west half Field 3	Davis	1914	850	50	3.5	1	1.01	15.1	15.0	0.84
Hofbenke	Los Molinos	1914	450	40	5.0	4	0.41	5.0	12.2	0.94
University Farm, west half Field 3	Davis	1915	880	50	3.5	1	1.01	10.9	10.8	1.48
University Farm, east half Field 3	Davis	1914	880	50	3.5	1	1.01	10.6	10.5	1.82
University Farm, west half Field 3	Davis	1914	880	50	3.5	1	1.01	10.0	9.9	1.17
University Farm, east half Field 3	Davis	1914	880	50	3.5	1	1.01	9.8	9.7	1.06
University Farm, Field 1B	Davis	1915	600	50	3.15	3	0.69	6.7	9.7	0.51
University Farm, east half Field 3	Davis	1915	880	50	3.5	1	1.01	9.7	9.6	1.70
Hermle	Woodland	1914	638	65	1.0	3	0.95	8.5	8.9	1.04
University Farm, east half Field 3	Davis	1914	880	50	3.5	1	1.01	8.8	8.7	2.78
University Farm, west half Field 3	Davis	1914	880	50	3.5	1	1.01	8.5	8.4	3.08
Hughson	Woodland	1914	1,270	82	3.5	1	2.40	15.3	6.4	2.00
McFarland	Gridley	1913	623	60	7.0	4	0.86	5.3	6.2	0.86
Hughson	Woodland	1914	1,270	82	3.5	1	2.40	9.6	4.0	2.23
Fisher	Woodland	1914	700	58	2.5	4	0.93	3.1	3.3	0.62
Huartson	Gridley	1913	610	65	2.5	4	0.91	2.4	2.6	0.66
Average									8.8	
Clay loams—										
Bratton	Gridley	1913	92	50	Level	4	0.11	1.9	17.3	0.96
Jackson-Woodard, south plat	Woodland	1914	449	40	3.5	3	0.41	4.4	10.7	0.63
Jackson-Woodard, north plat	Woodland	1914	478	40	2.5	3	0.44	4.3	9.8	0.71
Jackson-Woodard, south plat	Woodland	1913	449	40	3.5	6	0.41	3.8	9.2	0.51
Jackson-Woodard, north plat	Woodland	1913	478	40	2.5	6	0.44	3.8	8.6	0.56
Gulle	Woodland	1914	1,275	94	2.0	1	2.78	18.3	4.3	0.49
Gulle	Woodland	1913	1,275	94	2.0	4	2.78	12.0	4.3	0.54
Gulle	Woodland	1914	1,275	104	2.0	1	3.06	12.5	4.1	0.61
O'Hair	Orland	1914	1,250	40	2.5	3	1.15	3.4	3.0	0.35
Wright	Dixon	1913	99	92	Level	8	0.21	0.2	1.0	0.39
Average									7.3	
Clays—										
Brantley	Orland	1914	150	150	Level	18	0.52	2.7	5.2	0.22
Goos	Willows	1915	600	40	12.0	7	0.55	2.5	4.5	0.23
Goos	Willows	1914	600	40	12.0	10	0.55	1.9	3.5	0.18
Chambers	Los Molinos	1914	561	50	2.5	6	0.64	1.0	1.6	0.24
Cooper	Willows	1915	622	40	5.0	7	0.57	0.7	1.2	0.22
Average									3.2	

It is evident from the above summary that the most desirable head of water to use on any given soil can not be determined adequately by comparing use on different fields, especially when the applications have not been entirely under control, with a view to determining the best rates to follow. The present general practice in Sacramento Valley, expressed in cubic feet per second per acre, is, however, satisfactorily indicated from the average figures obtained, namely, 23 for gravelly loams, 10.9 for sandy loams, 8.8 for silt loams, 7.3 for clay loams, and 3.2 for clays. The difficulty of irrigating porous soils with small heads, and of irrigating clay soils with large heads is well recognized among irrigators, even if the most satisfactory relationships have not been worked out in detail.

While a comparison of the rates of application on different fields as given above fails to disclose the best size of heads to use, a comparison of the relation between irrigation heads and depth of application on single fields makes it plain that in many cases the heads should be increased, or even better, that the area of checks should be reduced. This is made clear by the following summary which gives the average heads used and the depths of water applied for those cases in which more than one observation for a single field provides a basis of comparison:

TABLE No. 19.

Summary of Rates of Application of Water and of Depths Applied at Different Irrigations of Five Individual Fields.

Soil type and name of field	Rate of application, cu. ft. per sec. per acre	Depths of water applied, feet
Sandy loams—		
Griffes, south plat	25.9	1.00
Griffes, south plat	19.4	1.41
Griffes, north plat	10.3	0.96
Griffes, north plat	8.2	1.00
Griffes, north plat	8.0	0.92
Griffes, north plat	6.0	1.11
Griffes, north plat	4.8	1.23
Silt loams—		
University Farm, west half Field 3	15.9	0.76
University Farm, west half Field 3	15.0	0.84
University Farm, west half Field 3	10.8	1.48
University Farm, west half Field 3	9.9	1.17
University Farm, west half Field 3	8.4	3.08
University Farm, east half Field 3	10.5	1.32
University Farm, east half Field 3	9.7	1.06
University Farm, east half Field 3	9.6	1.70
University Farm, east half Field 3	8.7	2.78
Hughson	6.4	2.00
Hughson	4.0	2.23
Clay loams—		
Jackson-Woodard, south plat	10.7	0.63
Jackson-Woodard, south plat	9.3	0.51
Jackson-Woodard, north plat	9.3	0.71
Jackson-Woodard, north plat	8.6	0.56
Guile	4.8	0.49
Guile	4.3	0.54
Guile	4.1	0.61
Clays—		
Goos	4.8	0.23
Goos	3.5	0.18

It is seen from the above summary that in each instance for sandy loam and for silt loam the depth of water applied increased with a decrease in the rate of application, although in individual cases, and by a small margin, there are exceptions. As already pointed out in connection with the quantities of water the different Sacramento Valley soils will retain against gravity, the depths applied in single irrigations in such instances as the Griffes and Hughson fields—from 0.96 foot to 1.41 feet on the former, and as high as 2.28 feet on the latter—are plainly excessive, and the figures given above make it evident that, when compared to the size of the checks, the irrigation heads used on such fields were too small. This deficiency in the rate of application is even more plainly marked in the case of University Farm field No. 3, on which the depth of water applied per irrigation ranged from 0.76 foot to 3.08 feet and averaged 1.58 feet.

If the above figures seem to lack somewhat in conclusiveness, data obtained in a single experiment at Davis in 1915 fully support the conclusion reached above. In this experiment measurements were made of the amount of water required to cover a one-acre check having a slope of three and one-half inches per 100 feet when applied at different rates. The data obtained were as follows:

Rate of application, cubic feet per second per acre	Depth of water required, feet
4.6	2.75
10.1	1.86
13.5	1.16
15.3	0.84
17.8	0.69

Until the proper relation between irrigating heads and size of checks is satisfactorily worked out in Sacramento Valley soil, there is sure to be, there as well as elsewhere, much difference of opinion as to whether small checks and correspondingly small irrigation heads or large checks and correspondingly large irrigation heads should prevail in the irrigation of alfalfa. Those who favor large checks and large heads base their preference chiefly on the greater rapidity with which irrigation can be accomplished with large heads, and also on the assumed lesser cost of preparing the land for irrigation. As a rule, where large heads are available they are used, and in some cases, as pointed out in connection with the heavy soils, especially the "water tight" soils found in some portions of the Willows area, the heads were plainly larger than they should be. In the case of individual pumping plants, which rarely discharge more than one or two cubic feet per second, checks necessarily are small. That waste of land goes with the large field ditches necessary in carrying large heads, and also that extravagant notions of use, and

a greater waste when breaks occur with large heads, are sound arguments in favor of small heads, can not be doubted. Thoughtful consideration by irrigators and intelligent advice by public agencies in time will work out that relationship which best will serve both irrigators and the public. In the mean time, it is very clear that irrigators should bear in mind the fact that the irrigation head should not be a constant quantity, but should be varied where practicable, with the different soils found on nearly every farm.

Desirable Moisture Percentages for Alfalfa in Sacramento Valley Soils and the Effect of Variation in Soil Moisture on Rates of Alfalfa Growth.

In interpreting the large number of soil moisture determinations made at Davis and on Sacramento Valley alfalfa farms from 1913 to 1915, account has been taken of the moisture percentages found as related to the percentages at which the plants would wilt, and also of the effect of the variation in those percentages on the growth of the alfalfa. The percentages at which the plants wilt, or the "wilting coefficients," have been computed on the basis of the experiments of Messrs. Briggs and Shantz of the Bureau of Plant Industry of this department.[1] As indicated by these experiments, the wilting percentage may be stated to be the point below which moisture in the soil ceases to be available to the plants, or, at least, below which it is obtained only with great difficulty. Due largely to the difference in the size of the soil particles, plants will wilt in clay soils when there is still an amount of moisture that in sandy soils would be ample for all plant requirements. In interpreting the figures that have been obtained, therefore, in so far as they relate to the rates of growth of the alfalfa, it must be kept in mind that the percentage of moisture above the wilting point, or, in other words, the available moisture, has the most significance.

The summary below presents the essential soil moisture data found, expressed as percentages of the dry weight of the soil and ranged in order of alfalfa yields, for eight plats on the irrigation tract on the University Farm at Davis, for 1915; for six plats on the experimental field at Willows, for 1915; and for 11 Sacramento Valley farms for either 1913 or 1914, together with the soil types, the depths of irrigation water applied, and the total yields. In this summary the total and available moisture percentages are given, and also the range between mean maximum and mean minimum percentages.

[1] U. S. Dept. Agr., Bureau of Plant Industry Bulletin 230. The wilting percentages, or "wilting coefficients," for the Sacramento Valley soils are based on the "moisture equivalents" of those soils as determined in the laboratory of the division of Soil Technology of the department of agriculture of the University of California in the course of these investigations. It might be noted here that the moisture equivalents are the percentages of moisture retained in the soil after the soil has been subjected to a centrifugal force equal to 1,000 times the force of gravity.

TABLE No. 20.

Depths of Water Applied, Yields of Alfalfa, Percentages of Moisture Present, and Wilting Percentages for 8 Experimental Plats at Davis, 6 Experimental Plats at Willows, and 11 Sacramento Valley Alfalfa Farms, Arranged in Order of Yields.

Plats or field	Location	Soil	Depth of water applied, feet	Annual yields of alfalfa, tons per acre	Average per cent of total soil moisture present	Per cent of soil moisture necessary for particular soil to prevent wilting ("wilting coefficient.")	Average per cent of available moisture present	Range in per cent of available soil moisture
22, 25	Davis	Silt loam[1]	3.00	8.63	14.95	10.35	4.60	5.41
Jackson-Woodard	Woodland	Clay loam	2.01	8.59	21.46	16.45	5.01	4.14
Bundy	Los Molinos	Silt loam	4.10	8.39	20.35	15.12	5.23	4.58
21, 26	Davis	Silt loam[1]	2.50	8.32	16.91	10.35	6.56	6.11
23, 24	Davis	Silt loam	4.00	8.05	17.50	10.35	7.15	6.74
D	Davis	Silt loam[1]	2.00	7.96	16.50	10.35	6.15	5.83
Griffes	Woodland	Silt and fine sandy loam	1.96	7.69	14.59	10.67	3.92	5.49
Beck	Woodland	Silt loam	1.59	7.28	16.55	13.80	2.75	2.63
O'Hair	Orland	Clay loam	1.04	7.17	16.55	11.55	5.00	3.25
Hughson	Woodland	Silt loam	2.91	6.96	15.38	12.74	2.64	6.77
Wigno	Los Molinos	Silt and fine sandy loam	6.08	6.68	17.77	12.14	5.63	5.31
19, 28	Davis	Silt loam[1]	1.50	6.46	14.65	10.35	4.30	5.38
Geer	Los Molinos	Clay loam	6.56	6.06	19.93	14.44	5.49	3.84
Hofhenke	Los Molinos	Silt loam	5.55	5.75	17.83	10.80	7.03	4.34
31	Davis	Clay loam	5.00	5.55	27.38	16.59	10.79	7.74
3, 4	Willows	Clay	2.00	5.07	12.63	11.60	1.03	0.78
18, 29	Davis	Clay loam	1.00	4.84	20.39	16.59	3.80	5.67
6, 7	Willows	Clay	2.00	4.42	13.15	12.54	0.61	1.80
11, 12	Willows	Clay	2.00	4.29	11.84	12.38	—0.54	2.73
Gulle	Woodland	Clay loam	1.14	4.28	16.99	14.41	2.58	3.40
Purdy	Willows	Clay	1.69	3.75	14.64	15.72	—1.08	1.61
17, 30	Davis	Clay loam	-------	2.35	17.36	16.59	0.77	

[1]With fine sandy subsoil.

Average wilting percentages as given above: Silt loams with fine sandy subsoils, 10.65; other silt loams, 13.12; clay loams, 14.21; clays, 13.06.

Average per cents of available moisture present: With yields over 8 tons per acre, 5.71; with yields from 6 to 8 tons per acre, 4.48; with yields under 6 tons per acre due to excess of water, 8.91; with yields under 6 tons per acre due to deficiency of water, 1.02.

Obviously, it is impossible to disregard the numerous soil and climatic factors other than soil moisture that affected the yields of alfalfa and then to expect the yields and moisture percentages to be consistent throughout.[1] However, by grouping the yields above eight tons per

[1]The low yields on the Tehama clays at Willows suggested the desirability of a chemical analysis of the soil from the experimental plat there. Samples were accordingly taken at depths of 4 and 20 inches and submitted for analysis to Dr. C. B. Lipman, professor of soil chemistry and bacteriology, college of agriculture, University of California. The results of the analysis, together with the comments of Dr. Lipman, follow:

	Per cent at depth of 4 inches	Per cent at depth of 20 inches
Nitrogen	0.059	0.036
Phosphoric acid	0.11	0.12
Potash	0.53	0.62
Lime	0.63	0.74

"These analyses show that the great deficiency of the soil is in nitrogen, undoubtedly both available and total. There is an ample supply of potash, by all the standards which we use at the present time as criteria. There is a quantity of lime, which, for that type of soil, is low, though for ordinary soils would be quite ample. Therefore lime should be added to that soil in larger quantity for the sake of the physical condition, though chemically speaking, the above figures would appear to be adequate. The phosphoric acid content shows adequacy, provided the root systems of the plants can have at least three feet of soil to feed on. Otherwise phosphate fertilizers will have to be employed."

acre, from six tons to eight tons per acre, and below six tons per acre, it is possible to approximate the best or "optimum" percentage of available moisture over and above the amount necessary in each soil to prevent wilting. Assuming the yields over six tons per acre to have been produced on soil having at least as much as the "optimum" percentage of available moisture, the summary indicates that the "optimum" for Sacramento Valley conditions ranges between about three per cent and about seven per cent and averages about five per cent above the wilting percentage.

For the Hofhenke field at Los Molinos and plat 31 at Davis, on both of which an excess of irrigation water was applied, the average available percentage was 8.91, or well above the "optimum." On the other hand, the average percentage of available moisture on experimental plats 3, 4, 6, 7, 11, and 12 at Willows, plats 17 and 30 and 18 and 29 at Davis, the Guile field at Woodland, and the Purdy field at Willows, for which either the application or the absorption of irrigation water was plainly deficient, was only 1.02, or well below the "optimum."

The column in the summary giving the percentages of moisture that must be present in the various Sacramento Valley soils dealt with in order to prevent wilting, and also the averages for the various soil types as given at the foot of the summary, are believed to be of value because they indicate to Sacramento Valley irrigators not only the difference between the clay, or "heavy" soils and the loams and sandy soils as regards the amount of soil moisture needed to prevent wilting, but also that for all of the soils the wilting percentage is higher than farmers usually suppose. If one could assume an absolutely dry soil it might be convenient for irrigators to know that, as disclosed in the investigations reported herein, the amount of water necessary to supply the wilting percentage is approximately the equivalent of about one and two-thirds inches of rainfall per foot of depth of soil in which the crop is growing in the case of the silt loams with fine sandy loam subsoils, of about two inches in the case of the other silt loams, of about two and one-fourth inches in the case of the clay loam, and of two and three-fourths inches or more in the case of clays such as those found at Willows.[1]

In other words, with an absolutely dry silt loam soil eight feet deep the first 16 inches of irrigation water would no more than supply the amount of moisture necessary to keep deep-rooting plants from wilting; or expressed still differently, with such a soil wholly devoid of moisture, the equivalent of a rainfall of two inches for each one foot depth of

[1]The soil moisture studies in connection with the clay soils at Willows disclosed lower wilting percentages and lower capacities to absorb irrigation water than were to have been expected. It is not intended to discuss this technical phase of the subject in the present report, and conclusions for all Sacramento Valley clay soils can not and should not be drawn from the experience reported herein with the Tehama clays under investigation at Willows.

soil the crop utilizes would need to be supplied before the roots of the crop could begin to utilize the moisture. Fortunately an absolutely dry soil is rarely found in Sacramento Valley, even at the end of the summer season, and except in very dry years the soils of Sacramento Valley are not likely to begin the spring growing season with less soil moisture than the wilting percentage. Those having clay or other heavy soils, however, should not fail to take note of the very low available moisture percentages, or the absence of any available moisture whatever, and the resulting very low yields of alfalfa, indicated in the bottom six lines of the summary. The figures given should make it very plain that soils into which irrigation water percolates with difficulty should be watched very carefully at depths from four to six feet below the surface. The experience of the field investigators at Willows indicated that this care is especially necessary even early in the summer in order to insure that an adequate irrigation supply shall replace the moisture absorbed from the winter rainfall after that has been utilized.[1]

Seasonal Duty of Water on Sacramento Valley Alfalfa Farms.

For the purpose of showing what portion of the total irrigation water used annually by Sacramento Valley alfalfa growers is applied in each month of the irrigation season, the figures obtained for 1913 and 1914 have been averaged and the results given in Table No. 20. It is to be noted that the monthly use differs slightly in different sections. The greater rainfall at Los Molinos and Gridley results naturally in a later beginning of irrigation in the spring and an earlier ending in the fall. Besides, there was no water shortage at either Gridley or Los Molinos during the two years of the investigation. Irrigation at Orland ended earlier in 1913 than in 1914 because of shortage of water. At Woodland, as explained in the text, in 1913, which was a year of scant rainfall and high prices for alfalfa, in nearly each case irrigation began in March, whereas in 1914, a year of ample supply but of low returns on hay, it did not begin on any farm before June, in some cases not before July, and in two cases not before August, when a single irrigation for the season was applied. It might be added that the figures for both Gridley and Dixon covered the year 1913 only.[2]

[1]What is said in the text regarding desirable moisture percentages for Sacramento Valley soils growing alfalfa considers the matter only from the standpoint of the total annual yields of hay. It is obvious, however, that the annual yields are results of conditions that vary from day to day and from week to week. For instance, considering the moisture factor only, annual differences in yield were results of the daily and weekly differences due to daily and weekly variations in soil moisture. The data collected have been studied with reference to the effect of these changing moisture percentages on the seasonal rates of growth, but as no data were collected to indicate daily or even weekly variations in rates of growth, making it necessary to rely on average rates of growth between cuttings, such deductions as were suggested in the study have not seemed sufficiently conclusive to warrant their presentation. It is, however, possible to say that where the moisture percentage was found to fall below the wilting point there was also found a definite falling off in the rate of alfalfa growth.

[2]For seasonal duty on individual farms see Cal. State Dept. Engineering, Bul. No. 1, pp. 51-53.

TABLE No. 21.

Summary of Seasonal Duty of Water for Alfalfa on 62 Sacramento Valley Farms, 1913 and 1914.

	March, per cent	April, per cent	May, per cent	June, per cent	July, per cent	August, per cent	September, per cent	October, per cent
Gridley	----------	----------	23.42	20.86	20.22	13.43	12.07	----------
Los Molinos	----------	----------	18.57	19.23	24.10	18.71	18.29	1.19
Orland	6.46	5.46	23.09	18.46	18.55	15.07	9.46	2.85
Willows	----------	----------	19.17	21.83	16.17	27.83	15.00	----------
Woodland	14.86	----------	16.47	17.10	31.05	7.09	11.67	1.76
Dixon	4.14	10.43	14.28	16.00	20.00	13.57	14.57	6.71
Averages	5.18	1.75	20.21	18.76	23.40	15.34	13.61	1.75

NOTE.—Averages for entire valley figured from all farms and not from section averages.

Cost of Irrigating and Handling Alfalfa in Sacramento Valley in 1914.

Records were kept in 1914 of the cost of irrigating and handling alfalfa in the sections of Sacramento Valley where alfalfa duty of water determinations were being made. The items covered the cost of cutting, raking, shocking, stacking and baling. The average total cost of the first four of these items was $1.88 per ton. The cost of baling in Sacramento Valley ranged from $2 to $2.25 per ton. The prevailing prices of labor in Sacramento Valley were $2 to $2.50 per day per man and $1 per head for stock. The usual price for a man applying water was 25 cents per hour. The data gathered, averaged for the separate sections and for all of them taken together, are summarized in Table No. 21.

TABLE No. 22.

Cost of Irrigating and Handling Alfalfa, Sacramento Valley, 1914.

Area	Annual cost of irrigation per acre		Total cost of handling crop, per ton of hay						Total seasonal cost of handling crop, per acre	Total of all irrigation and handling costs, per acre
	Applying water, including cleaning of ditches where this is a factor	Water charges, or cost of pumping	Cutting	Raking	Shocking	Stacking	Baling	Moving baled hay		
Woodland average	$0 92	$2 56	$0 28	$0 14	$0 20	$0 79	$2 14	$0 65	$12 79	$16 51
Los Molinos average	1 61	2 00	50	21	26	82	-------	-------	10 35	13 95
Orland average	2 14	2 00	53	23	34	89	-------	-------	11 46	15 59
Willows average	1 25	1 75	67	36	30	1 09	-------	-------	7 23	10 23
General average	$1 48	$2 08	$0 49	$0 23	$0 27	$0 89	-------	-------	$10 45	$14 07

[1]Do not include interest, depreciation, etc., or other similar "overhead" charges.

In comparing the costs for the different areas it should be borne in mind that the cost of water, the number of irrigations, and the number of crops cut were not the same in the different sections. For instance,

the highest cost per acre was at Woodland, where the charge for water was higher than elsewhere. The lowest cost was at Willows, where it was found more profitable to pasture the fields after two or three crops had been removed. The cost of applying water at Orland was about double that of other sections owing to the larger number of irrigations given between cuttings. The usual price received for alfalfa hay in 1914 was $4 per ton in the stack and $6.50 per ton baled.[1]

SUMMARY AND CONCLUSIONS.

1. This bulletin discusses observations of the duty of water made under the direction of the Office of Experiment Stations or the Office of Public Roads and Rural Engineering from 1910 to 1915, inclusive, at the California University Farm at Davis, on 54 Sacramento Valley alfalfa farms near Gridley, Los Molinos, Orland, Willows, Woodland, and Dixon, during 1913 and 1914, and on an experimental tract near Willows in 1915.

2. Soils, representative of extensive areas in Sacramento Valley, including the Madera, Gridley, Vina, Tehama, Elder, and Yolo series, were included in the investigations. The various fields represented classes of soil varying in texture from the gravelly loams of the Elder series to the clays of the Tehama series.

3. The water used on the alfalfa fields was measured by current meters or weirs and its underground distribution was ascertained by soil borings shortly before and shortly after irrigations and by about 11,000 soil moisture determinations.

4. Average annual depths of water applied were found to vary from 1.83 feet in the Willows area to 5.15 feet in the Los Molinos area, and on a single field the smallest annual application was 1.04 feet on a clay loam, as compared to 9.59 feet, on a gravelly loam, both of which were at Orland.

5. With the exception of the highly permeable Elder gravelly loams at Orland and the very impervious Tehama clays and clay loams at Willows, the results of the work, as a whole, are in agreement with the results of the six-year duty of water study at Davis. These have indicated that a depth of from 30 to 36 inches of water annually is the most desirable quantity of irrigation water to apply under general Sacramento Valley conditions. Total depths of less than 24 inches annually, exclusive of rainfall, are insufficient for satisfactory yields as indicated by the Willows work, while application of depths of 48 or more inches per year do not produce corresponding increases in alfalfa yields.

[1] For detailed costs on the individual farms see Cal. State Dept. Engineering Bul. No. 1, pp. 30-31.

6. Not counting the experimental plats at Davis or at Willows, moisture determinations were made chiefly on 15 fields, of which 13 were of silt loams or clay loams. In the case of all but one of these loam soils, for which one the full capacity of the soil to retain water was not satisfied, the average quantity of irrigation water retained per irrigation in the upper six feet of soil was equivalent to a depth of only 4.31 inches, or only 32.6 per cent of the average individual applications, and only 0.72 acre-inch per acre per foot in depth of the soil. Although the roots of alfalfa penetrate in these soils to a greater depth than six feet, it is plain that a considerable portion of the irrigation water went below the zone of greatest root activity and was largely or wholly wasted.

7. Considering the quantities of irrigation water retained in the upper six feet of soil for all of the fields for which soil moisture determinations were made, it is found that the average quantity retained in the lighter and more permeable soils was 0.92 acre-inch per acre for each foot in depth of soil, or the equivalent of five to six acre-inches per acre for six feet of soil, whereas the clay soils absorbed an average of only 0.37 acre-inch per each acre-foot of soil, or at the rate of only about two and one-quarter acre-inches for six acre-feet, due to their great imperviousness in their present condition. In the surface foot, however, the light soils retained an average of 1.04 acre-inches per acre-foot of soil as compared to 1.71 acre-inches per acre-foot held by the clay soils, this being in accordance with the well-known fact that clay soils, when thoroughly wetted, will hold much more soil water than soils of coarser or "lighter" texture.

8. Averaging the quantities of irrigation water retained by each field for which moisture determinations were made, it is found that the maximum quantities retained per acre-foot of soil per irrigation were 1.02 acre-inches for the silt loams with fine sandy subsoils, 0.75 acre-inch for the silt loams without fine sandy subsoils, 0.78 acre-inch for the clay loams, and 0.49 acre-inch for the clays.

9. Considering only the moisture determinations from the surface foot of soil of the 15 farms and the three Willows experimental plats for which such determinations were made—in each case the surface foot held its full capacity of irrigation water—it is plain that, in the case of the typical silt loam soils of Sacramento Valley, single applications of irrigation water exceeding depths of one to one and one-half inches per foot in depth of soil it is necessary to moisten accomplish no useful purpose. While the typical clay loams and clays of Sacramento Valley will retain against gravity in their normal growing condition as much as one and one-quarter to one and three-quarters acre-inches of irrigation water per acre-foot of soil, over and above the amount normally found in such soils under Sacramento Valley field

conditions, that amount of irrigation water will not be absorbed by these soils unless it is applied very slowly.

10. The wilting percentages or "wilting coefficients" for the Sacramento Valley soils under investigation ranges from 10.35 in the case of the silt loams of the experimental irrigation tract on the University Farm, at Davis, to 16.59 in the case of clay loam on the same tract. The average wilting percentages for the several types of soil under observation were 10.65 for the silt loams with fine sandy subsoils, 13.12 for the other silt loams, 14.21 for the clay loams, and 13.06 for the clays. The approximate quantities of water necessary to apply to thoroughly dry soils of the types listed to bring the moisture content up to the wilting points given are, in inches in depth per foot of soil, 1.5 for the silt loams with fine sandy subsoils, 2 for other silt loams, 2.3 for the clay loams, and 2.6 for the clays.

11. The optimum percentage of available soil moisture for Sacramento Valley alfalfa soils, over and above the percentage at which wilting occurs, seems to average between four and six per cent. This is equivalent to depths of from 0.6 to 0.9 inch of irrigation water per foot of soil for loam soils and of from 0.7 to 1.2 inches per foot of soil for the heavier clay loams and clays.

12. Alfalfa planted on very open and very impervious soils should be irrigated more than once between cuttings. This is necessary in the case of the open soils because of the inability of such soils to retain all of the moisture needed to mature a crop, and in the case of the impervious clay soils in order to accomplish deeper penetration of the irrigation water into them. In the case of the latter soils it is very desirable that the moisture supplied by winter rains shall be supplemented by irrigation water sufficiently early in the spring to prevent drying out. The frequent use by irrigators on such soils of a soil auger is to be urgently recommended, the investigations reported herein having demonstrated that penetration of irrigation water into the clay soils is very much less than irrigators usually realize.

13. Under the present general practice on the Sacramento Valley alfalfa farms under observation, the applications of irrigation water, expressed in cubic feet per second per acre, averaged 23 for gravelly loams, 10.9 for sandy loams, 8.8 for silt loams, 7.3 for clay loams, and 3.2 for clays. As checks seldom are as much as one acre in area, the actual irrigating heads usually were less than these figures. Where excessive quantities of irrigation water have been applied the reason very frequently has been the use of too small irrigating heads or of too large checks. Additional data are necessary to give a satisfactory basis for definite recommendation as to rates of application. It is already clear, however, that irrigating heads that are not large enough to enable

alfalfa checks to be watered evenly with six acre-inches of water per acre per irrigation are too small, and the remedy is either larger irrigating heads or smaller checks, preferably the latter, especially in the case of the smaller holdings.

14. Dimensions and grades of alfalfa checks vary somewhat in the six sections of Sacramento Valley studied. Some square and rectangular checks are used in each section but border or "strip" checks are most common, except on the gravelly soils at Orland, where the most satisfactory check probably is one about 100 feet square, containing a little under one-fourth acre, and with each check having direct access to a field lateral to do away with carrying water to one check over another. The border checks range from 30 to 120 feet in width and from 60 to 1,750 feet in length, the most usual width being from 30 to 50 feet and the most usual length from 400 to 700 feet. The grades of border checks range from 0.6 to 12 inches per 100 feet and average 3.6 inches per 100 feet.

15. Irrigation of alfalfa in Sacramento Valley is confined to the months March to October, inclusive, and in 1913 and 1914 it was confined to the months May to September, inclusive, at Gridley and Willows, and May to October, inclusive, at Los Molinos. Considering the entire six districts in which the investigations were made, the average percentage of the total annual use that was applied in each month of the irrigation seasons of 1913 and 1914 was as follows: March, 5.18; April, 1.75; May, 20.21; June, 18.76; July, 23.40; August, 15.34; September, 13.61; October, 1.75.

16. The general averages of the various items making up the cost of irrigating and handling alfalfa in Sacramento Valley in 1914 on 28 farms were as follows: Applying water, including cleaning of ditches, $1.48 per acre; water charges, or cost of pumping, $2.08 per acre; cutting, $0.49 per ton; raking, $0.23 per ton; shocking, $0.27 per ton; stacking, $0.89 per ton; total for handling crop, per acre, including cost of baling, $10.45 per acre; total of all irrigation and handling costs, $14.07 per acre.

STATE OF CALIFORNIA
DEPARTMENT OF ENGINEERING

APPENDIX D

Preliminary Report on Conservation and Control of Flood Water in Coachella Valley, California

By C. E. TAIT, Irrigation Engineer, Office of Public Roads and Rural Engineering, United States Department of Agriculture.

(Based on data gathered under cooperative agreement between the Office of Public Roads and Rural Engineering of the United States Department of Agriculture, the California State Department of Engineering, and the University of California Agricultural Experiment Station and reprinted from the Fifth Biennial Report of the Department of Engineering.)

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COACHELLA VALLEY
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PRELIMINARY REPORT ON CONSERVATION AND CONTROL OF FLOOD WATER IN COACHELLA VALLEY, CALIFORNIA.

By C. E. TAIT, Irrigation Engineer, Office of Public Roads and Rural Engineering, U. S. Department of Agriculture.

Description.

Coachella Valley is located in Riverside County, California, east of divide between Pacific Ocean and Colorado Desert, and it comprises a neck of the desert which slopes southeastward from the summit of the Coast Range towards the Salton Basin, the lowest depression of the desert. The valley has not taken its name from any stream which enters or crosses it and it might have been named after Whitewater River, which is the trunk of its drainage. The territory to be considered in connection with the conservation and storm water problems of Coachella Valley may for convenience be divided into a number of general divisions which are best understood by reference to the accompanying map, Pl. I.

Valley Areas.

Beginning at the northwestern extremity of the territory, it is instructive to consider three general areas, the eastern slope of San Gorgonio Pass, Coachella Desert and Coachella Valley. San Gorgonio Pass is flanked on north and south by the higher mountains of the Coast Range and it collects much of the drainage of the headwaters of Whitewater River. The divide is between Beaumont and Banning and the pass extends eastward to Whitewater. This area contains 32,000 acres. Coachella Desert extends from Whitewater to Point Happy and contains 78,000 acres. Coachella Valley extends from Point Happy to the Salton Basin and contains 145,000 acres.

Drainage Areas.

The limits of the mountain watersheds of Whitewater River and tributaries are shown on the map by dashed lines. The sheds may be considered in groups. The two most important are the southeastern slopes of the San Bernardino Mountains culminating in Mt. San Gorgonio and lying north of San Gorgonio Pass and the northeastern slopes of the San Jacinto Mountains lying south of the pass and centralized around the peak of the same name. The northeastern slope of the Santa Rosa Mountains draining into Coachella Valley on the southwest side is of less importance, while the drainage toward the valley on the northeast side is of little consequence.

The area of mountain watershed is as follows:

	Square miles.	
San Bernardino Mountains, drainage to San Gorgonio Pass—		
San Gorgonio River	28	
Potrero and Hathaway creeks	22	
Millard Canyon	16	
Streams between Millard Canyon and Whitewater River	22	
Whitewater River	62	
		150
San Bernardino Mountains, drainage to desert—		
Mission Creek	46	
Big and Little Morongo creeks	100	
		146
San Jacinto Mountains, drainage to San Gorgonio Pass—		
Small streams above Snow Creek	40	
Snow Creek	23	
		63
San Jacinto Mountains, drainage to desert—		
Streams between Snow and Tahquiz creeks	18	
Tahquiz Creek	20	
Palm Canyon	126	
		164
Santa Rosa Mountains, drainage above Point Happy—		
Streams between Palm and Deep canyons	19	
Deep Canyon with Dead Indian Creek	65	
		84
Santa Rosa Mountains, drainage below Point Happy—		
Streams between Deep and Martinez canyons	48	
Martinez Canyon	52	
Streams below Martinez Canyon	60	
		160
Eastern extension of San Bernardino Mountains, drainage—		
Streams between Morongo Creek and Salton Sea		430
Total		1,197

Whitewater River is the largest stream of the mountain drainage in both maximum rate and annual amount of discharge. Its watershed, although not the largest, embraces a larger area at high elevation than any other branch and its summer flow is kept up by the slow melting of snow on Mt. San Gorgonio. This stream falls from an elevation of 11,485 feet at the summit of the peak to 1,400 feet at the mouth of the canyon in 20 miles, or at the rate of 504 feet per mile. The mouth of Whitewater Canyon is shown by Pl. II, Fig. 1.

San Gorgonio River is a more extended branch of the Whitewater drainage than the Whitewater itself and is the second stream in size entering San Gorgonio Pass. Millard Canyon and Potrero Creek flow in small amount through the summer.

Mission and Big and Little Morongo creeks, although having a large watershed, do not drain an area of as high precipitation as streams entering the pass.

Snow Creek, which drains the north slope of Mt. San Jacinto, and Tahquiz Creek, which drains the eastern slopes of San Jacinto and

Plate II, Fig. 1 (upper).—Looking up stream at mouth of Whitewater Canyon April 3, 1916, showing coarseness of gravels at the head of the debris cone. Fig. 2 (lower).—Mouth of Santa Ana Canyon.

Tahquiz peaks, are remarkable for being precipitous. It is doubtful if their grades are equaled by those of any other streams of equal or greater length in western United States. Snow Creek falls from the summit of Mt. San Jacinto at elevation of 10,805 feet to 1,250 feet in San Gorgonio Pass, or at the rate of 1,365 feet per mile for its entire length, while Tahquiz Creek falls 10,305 feet from the same summit to the desert at Palm Springs in 10 miles at the rate of 1,030 feet per mile. The flow of Tahquiz Creek is much more constant than Snow Creek for the reason that the former has its source in mountain flats, while the latter is precipitous from its extreme source. Pl. III, Fig. 1 is a view of Tahquiz Creek at Palm Springs.

Palm Canyon, shown by Pl. IV, Fig. 2, has the largest watershed of any tributary of the Whitewater, but the shed is not so high as others and the length of the canyon, 20 miles, regulates the discharge so that its floods are not troublesome.

Deep Canyon drains the north slope of the summit of the Santa Rosas with elevation of 8,705 feet, and while the rainfall here is much less than on the San Bernardinos and San Jacintos, the stream is of some importance in the flood water problem owing to the fact that it empties into the valley only a few miles above the agricultural lands and at a point so far down the valley that its discharge occurs on silt rather than on the more absorbent gravels.

Martinez Canyon enters the valley so near the lower end that its floods do not menace property to great extent, although a well-defined debris cone below the mouth of the canyon gives evidence of the occurrence of storm water. The crest of the range and the base line of the eastern extension of San Bernardino Mountains are shown on the map from the unpublished plats of new surveys of the United States Land Office. This area is large, but the run-off is very light.

Stream Discharge.

Unfortunately there are but few records of measurements of the discharge of Whitewater River and tributaries. The only authentic measurements available are the following fragmentary measurements by the United States Geological Survey:

Whitewater River.		
Feb. 16, 1898.	At foot of Bear Valley trail	14.20 sec. ft.
Feb. 17, 1898.	Two miles above mouth	17.80 sec. ft.
Feb. 17, 1898.	North fork at mouth, 5.64 sec. ft. Middle fork at mouth, 0.82 sec. ft. South fork at mouth, 7.42 sec. ft.	12.88 sec. ft.
Mar. 4, 1899.	At mouth	2.52 sec. ft.
Snow Creek.		
Feb. 22, 1898.		4.50 sec. ft.

On April 3, 1916, the following estimates of discharge were made from observation:

Whitewater River at mouth of canyon	75 sec. ft.
San Gorgonio River at S. P. railroad	20 sec. ft.
Millard Creek at S. P. railroad	5 sec. ft.
Tahquiz Creek at mouth of canyon	30 sec. ft.

On this date Palm Canyon at mouth, Deep Canyon at mouth, and Guadalupe Creek at mouth were dry, although all were reported to be flowing in the canyons. Martinez Canyon was not visited, but was probably flowing in the canyon but not in the wash below the canyon. Snow Creek was discharging a small stream down the side of Mt. San Jacinto, but the water was not reaching Whitewater as surface flow. It was also observed that the combined waters of San Gorgonio River and Millard Creek were sinking just above the point of rocks between Cabazon and Fingal and that the flow of Tahquiz Creek was being lost about three miles below the canyon. On March 29, 1916, the water in Whitewater River was all disappearing in the vicinity of Palm Springs station and no surface water from Mission Creek was reaching as far down as the Southern Pacific Railroad. These measurements and observations give but little idea of the flood discharge.

Character of Watershed.

Most of the mountain watersheds of the Whitewater and tributaries in San Bernardino Mountains, San Jacinto Mountains and some of those in Santa Rosa Mountains are within the national forest reservations. Mt. San Gorgonio and Mt. San Jacinto reach above timber line, which in southern California is at about 9,000 feet elevation. Generally the northern slopes of the mountains are more heavily timbered than the southern, but this does not hold true for Mt. San Jacinto because its northern slope is of granite and so precipitous that trees have little chance to take root. Pine timber grows on the upper slopes of the San Bernardinos and San Jacintos and the lower slopes are generally covered with brush consisting mainly of sumac, mountain mahogany, buckthorn or wild lilac, and chamiso, commonly called greasewood. The growth on Santa Rosa Mountains is more sparse, while the eastern extension of the San Bernardinos is nearly barren of chaparral.

Precipitation.

The only rainfall stations maintained by the United States Weather Bureau within the Whitewater drainage have been at Indio, Palm Springs and Salton in the valley, and at Cabazon in the mountain pass. The gage at Beaumont is nearly within the area while that at Seven Oaks in San Bernardino Mountains and that at Idyllwild in San

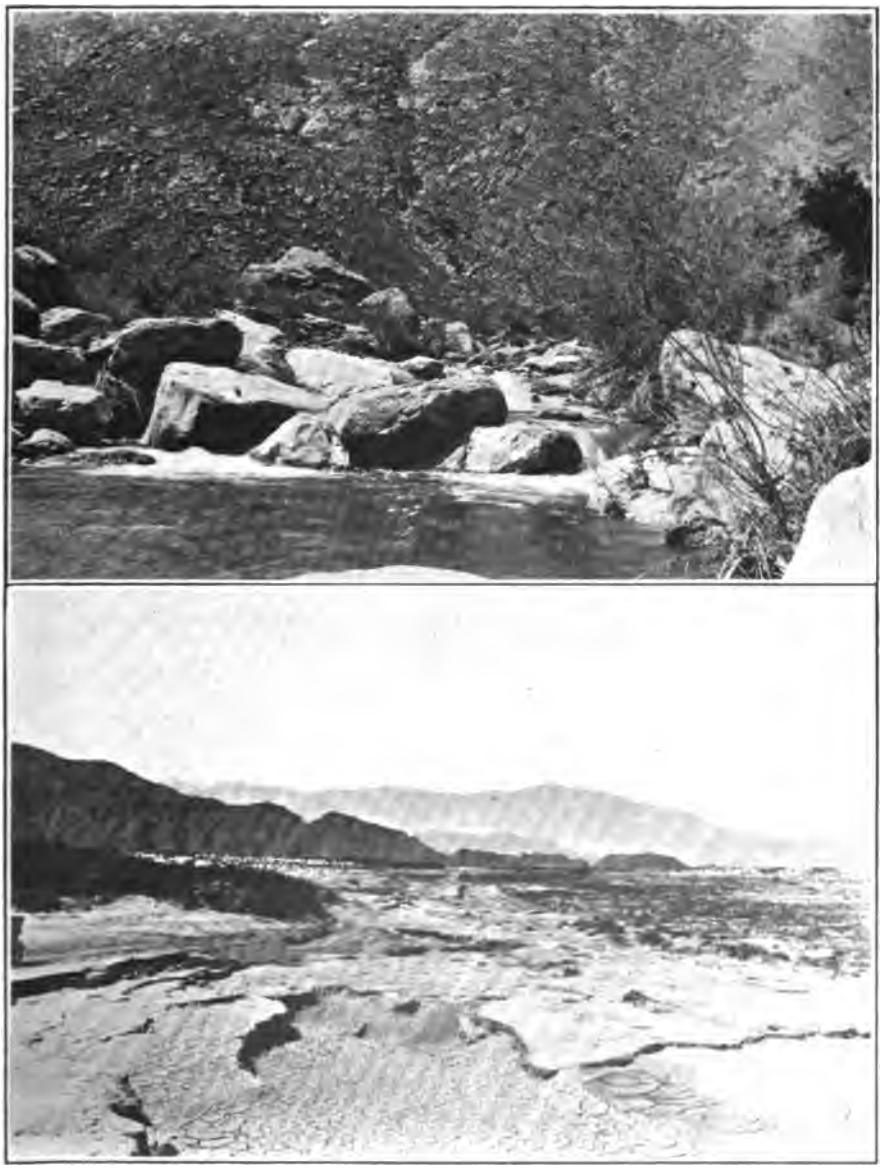

Plate III, Fig. 1 (upper)—Tahquiz Creek at Palm Springs. This stream is one of the most precipitous in the United States, falling 1,030 feet per mile. Fig. 2 (lower).—Looking up Whitewater channel to Point Happy. Mount San Jacinto in the distance.

Jacinto Mountains are a few miles over the divide on western slopes where the precipitation is greater than at the same elevation on the eastern slopes. The recorded seasonal rainfall in inches for these stations is as follows:

	Indio, elevation 20 ft.	Palm Springs, elevation 584 ft.	Salton, elevation 263 ft.	Beaumont,* elevation 2,600 ft.	Cabazon, elevation 1,779 ft.	Seven Oaks, elevation 5,050 ft.	Idyllwild, elevation 5,250 ft.
1878-79	1.90						
1879-80	.40						
1880-81	4.65						
1881-82	1.50						
1882-83	3.04						
1883-84	5.60						
1884-85	.80						
1885-86	.90						
1886-87	1.35						
1887-88	.95						
1888-89	3.83						
1889-90	5.56	5.86	4.37				
1890-91	2.42	8.57	4.51				
1891-92	4.24	3.99	3.88				
1892-93	1.63	1.68	.92				
1893-94	1.01	3.96	1.59				
1894-95	6.01	7.75	1.53				
1895-96	.92	4.34	0				
1896-97	1.29	0	3.87	20.71			
1897-98	2.50	1.69	.85	11.30			
1898-99	1.70	2.03	.89	7.78	5.79		
1899-00	2.35	4.78	.84	11.28	6.56		
1900-01	3.04	4.79	3.70	20.61	11.32		
1901-02	.60	1.50	1.38	18.51	7.70		19.43
1902-03	2.35	2.10	3.25	21.87	11.62		26.48
1903-04	2.05	.35	.40	11.98	6.67		14.95
1904-05	5.18	9.35	9.29	29.30	17.88		35.01
1905-06	4.70	5.70	.58	23.19	18.36		41.66
1906-07	5.83	4.75	5.97	26.08	16.64		30.66
1907-08	3.18	3.03		17.79	8.40		21.31
1908-09	3.13	4.35			16.67		35.34
1909-10	3.60	5.16					25.35
1910-11	2.44	6.47				30.96	27.82
1911-12	2.62	4.05		17.56		17.78	
1912-13	3.01	5.38		10.23		13.73	
1913-14	2.45	5.72		27.48		38.57	
1914-15	5.43	7.35		28.61		41.55	
Mean	2.82 37 seas.	4.36 26 seas.	2.66 18 seas.	19.02 16 seas.	11.60 11 seas.	28.52 5 seas.	27.80 10 seas.

*First twelve seasons from private record.

The mean monthly rainfall for Indio, 1877 to 1912, and for Idyllwild, 1901 to 1912, the one being in the valley and the other in the mountains, is as follows:

	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June
Indio	.01	.18	.17	.11	.21	.47	.72	.45	.31	.07	.03	.00
Idyllwild	.50	1.29	.65	.92	2.16	2.27	5.33	4.65	6.60	1.86	1.18	.06

The greatest precipitation for any month during the period for which measurements were made prior to 1916 was as follows:

Station	Rainfall	Month
Salton	5.12	Feb., 1889
Indio	6.01	Jan., 1896
Palm Springs	7.44	Feb., 1891
Cabazon	9.09	Mar., 1906
Beaumont	10.15	Mar., 1906
Idyllwild	16.15	Mar., 1906
Seven Oaks	16.83	Feb., 1915

From all accounts the flood of January 17, 1916, was the highest in 18 years, if not the highest, ever observed in Whitewater River by the settlers of Coachella Valley. The rainfall for January, 1916, was as follows:

Day	Seven Oaks	Beaumont	Cabazon	Palm Springs	Indio
January 1	.65				
January 2					
January 3					
January 4	.50	.12			
January 5	1.02	.35			
January 6					
January 7					
January 8	1.40	.50			
January 9	.25	.26	.20		
January 10	1.01	.50		.80	
January 11					
January 12					
January 13					
January 14	.52	.28			
January 15	.27	1.52			
January 16	5.60	2.08	.20	.30	.94
January 17	6.10	2.20	4.20	1.00	1.10
January 18	3.40	1.71	4.60	1.00	.52
January 19	.43	.70	2.10	.75	
January 20			2.30	.35	
January 21					
January 22					
January 23					
January 24	.25	.56			
January 25	1.00	.67			
January 26	2.25	1.58	.50		
January 27	6.45	2.70	.10	1.00	.97
January 28	.10	.08			
January 29	.35	.35			
January 30					
January 31					
	31.10	16.16	14.20	5.20	3.53

In the absence of measurements the following estimate of the flood of January 17, 1916, based on the run-off of the western mountain slopes of San Diego County, is offered:

	Square miles	Second-feet per square mile	Second-feet
San Bernardino watershed	296	200	5,920
San Jacinto watershed	227	150	3,400
Santa Rosa, above Point Happy	84	100	840
Total at Point Happy			10,160

It is difficult to make comparisons between streams on the eastern and western slopes of the mountains as the conditions are different. The precipitation for a year or a month or perhaps for a day is greater on the western than on the eastern slopes, but the precipitation for a storm of a few hours duration is sometimes very heavy on the eastern side of the range and the short but violent storms may cause heavy floods. Another difference is in the rapidity of run-off. The slopes are steeper on the desert side of the range and there is less vegetation to retard the run-off than in the more humid territory draining to the Pacific Ocean.

Use of Surface Water.

Irrigation development in Coachella Valley will be limited by the amount of water available. Only a small proportion of the land can be irrigated from the Whitewater drainage. The normal summer surface flow of the streams, excepting that from Whitewater Canyon, is already all appropriated and used for irrigation. The flow of San Gorgonio Canyon, which averages about 11 second-feet in summer, is diverted and used by the Banning Water Company at Banning. The company claims the entire flow and has a system for the irrigation of 2,700 acres. The stream supply is supplemented by wells below the canyon. The company spreads flood water over the gravel cone below the canyon in winter for the benefit of the wells.

The flow of Potrero Creek is used by the Indians for the irrigation of 1,300 acres of land on the Morongo reservation. The discharge of Millard Canyon is conveyed to Cabazon where it is used on lands under the system of the Cabazon Water Company. Mission Creek supplies water to 160 acres on the Mission Creek Indian reservation at the mouth of the canyon. Tahquiz and Andreas creeks furnish water for 200 acres on the Agua Caliente Indian reservation at Palm Springs and the area irrigated on this reservation is to be doubled. A small area is also irrigated on the Santa Rosa reservation at the headwaters of Palm Canyon.

A small ditch diverts water from the Whitewater at the mouth of the canyon for use on a single ranch. The Rogers Ditch takes water from the river at the point of rocks near Whitewater and carries it eight miles to Palm Springs settlement where the water is sold to users. This conduit is cobble-lined and has a capacity of seven second-feet.

About 1913 the Consolidated Reservoir and Power Company completed a conduit which diverts water from Middle and South Forks of Whitewater River in the mountains at 7,000 feet elevation and carries it six miles across the divide to San Gorgonio River from which it is used for irrigation at Banning. This conduit is in the main a concrete lined ditch 24 inches deep by 18 to 20 inches wide on a grade of 20 feet per mile, constructed to carry two and one-half second feet. Two undertakings known as the Pluth projects solely for the development of power on the headwaters of the Whitewater have been proposed. Rights of way through the forest reservation have been secured but the works have not been constructed. Several small private ditches which do not have a permanent water supply are located in canyons along the southwest side of the valley and mountain pass and late water filings have been made on Snow Creek and other streams in the pass, but so far as is known the claims have not been followed by construction, appropriation and use. Ditches and main pipe lines are shown on the map in heavy solid lines and projected power development conduits are shown in heavy dotted lines.

Underground Waters.

All irrigation in Coachella Valley below Point Happy is from wells. The underground water on which the wells are dependent has its source in the precipitation over the mountain drainage. The light rainfall on the valley and desert areas is mainly disposed of by evaporation in the dry atmosphere. Except for short and infrequent periods of high flood, all water not diverted by ditches is taken up by the gravels on which the canyons debouch.

During the summer or season of regular irrigation in San Gorgonio Pass but little water is allowed to reach the gravel cones from any but Whitewater Canyon. This stream normally sinks between the canyon and Palm Springs Station. The water absorbed by the gravels below the canyons moves toward Salton Sea and its gradient conforms in general to the slope of the land. If more borings were made between Whitewater Canyon and Point Happy it is probable that a number of different water planes might be established. As would be expected, a cienega is located just above Point Happy where the ground water is held up nearly to the surface by the obtrusive granitic point giving rise to the old Indian wells. Pl. III, Fig. 2 is a view of Point Happy with San Jacinto Peak in the distance.

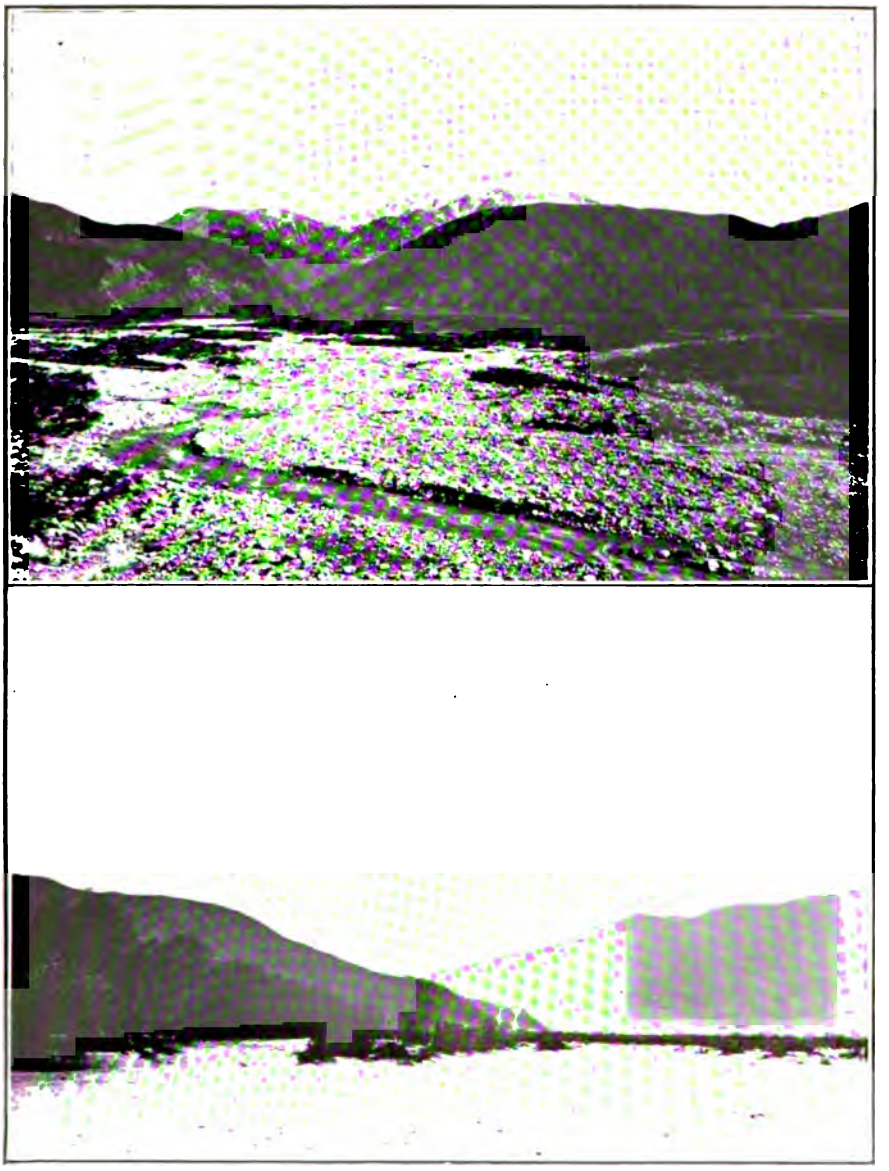

Plate IV, Fig. 1 (upper).—Gravels below Mill Creek Canyon. Fig. 2 (lower).—Palm Canyon near mouth, showing dry channel characteristic of the desert except in storm period. Palms are native to portions of this canyon.

Effect of Precipitation on Underground Water.

The rate of movement of the underground water is very slow. The highest rate of movement found for subterranean flow of such streams in southern California as San Gabriel, Los Angeles and Mojave rivers was about five miles per year, while the fluctuations in ground water levels generally lag one year or more behind seasons of heavy precipitation in the mountains. Owing to the distance and to the fine materials through which the water must percolate it is probable that it takes more than two years for the effect of precipitation to reach the artesian basin in the valley. This slow travel of the water regulates the effect at the lower end of the valley so that there is little noticeable response in the ground water level to a single year's precipitation, but a relation between source and destination must exist and for reasonable permanence in the ground water level the output from wells in the valley can not in general exceed the input to the gravel cones above.

Slope of Land and Water Plane.

The grade from Banning to Palm Springs station is 82 feet per mile, from Palm Springs to Indio 30 feet per mile, and from Indio to Mecca 17 feet per mile. Direct comparison can not be made between the profiles of the water plane and the land surface, for no wells have been bored along the railroad track above Indio.

Some idea of the water gradient may be had from the following: Water was struck at 72 feet, and it rose to 45 feet from the surface in the Warner well in Sec. 14, T. 3 S., R. 4. E., at Seven Palms. The well in SE. ¼ Sec. 18, T. 3 S., R. 5 E. flows lightly, probably due to interception of the underflow of Mission Creek by the hills near Seven Palms. The well located in Sec. 2. T. 5 S., R. 5 E., and on Whitewater wash about midway between Palm Springs and Point Happy, reaches water at 87 feet, and is 153 feet deep, penetrating 60 feet of water-bearing gravel. The McDonald well in Sec. 20, T. 5 S., R. 6 E., and three and a half miles above Indian Wells, reaches water at 100 feet. This well is 250 feet deep and delivers one second-foot when pumped. Another well being drilled on the same site is now at 420 feet, and is to be 700 feet deep. Springs and shallow wells dug show the ground water to be practically at the surface at Indian Wells, one mile above Point Happy. The underground water is here held up by the extension of the point now buried by the alluvium. After passing over or around the intercepting ridge, it soon drops to a lower level for the wells on the date orchards one mile west of Indio and at sea level reach water at 50 feet. Below Indio the water plane appears to have a uniform slope about one-half as great as the ground surface until it meets the surface at the edge of the artesian area between Coachella and Thermal at elevation

100 feet below sea level. The logs of wells drilled in the valley show alternating layers of clay, sand and gravel with various arrangements.

Wells.

Development of Coachella Valley began about 1894 and most of the wells have been drilled since 1900. Including irrigation and domestic wells, over 400 have been drilled, of which 300 originally flowed. About 1900 the artesian area included practically all land below the 100-foot contour below sea level and land around Indio up to the sea level line, an area of 140 square miles. Owing to the boring of new wells with increased draft on the basin and the effect of dry years 1897 to 1904, the artesian area contracted since 1905. The recession of the underground water level has apparently been to some extent checked by the seasons of more plentiful rainfall beginning 1905, yet the general tendency is to lower, and at present no wells above Coachella flow. The 100-foot contour below sea level about midway between Coachella and Thermal is approximately the upper limit of the artesian area at present, while at the sides of the valley the limits are lower, the area being only about one-half the original.

During the early period the wells were generally bored to depths of 400 or 500 feet. After the reduction of the artesian area some wells were bored 800 to 1,200 and one 1,400 feet deep, penetrating lower water-bearing strata. These gave larger and stronger flows than the more shallow wells, but it is not certain that the flow from the lower strata will be more permanent than from the upper. At the present time most of the drilling is to depths of about 600 feet, for if pumping must be resorted to, a medium depth gives as good results as a greater depth of well. The wells as located by the United States Geological Survey in 1907 are shown on the map in small circles. Those with a dot within the circle indicate pumped wells. About 150 wells, including some that flow lightly, are now pumped. The flow of the wells is generally less than one-half a second-foot. Some deliver over one second-foot when pumped. The water from the wells is of good quality. The temperature of most of the well water ranges from 75 to 90 degrees, the higher temperatures being for wells near Salton Sea. A new well near Martinez is reported to produce water with temperature of 106 degrees. The discharge of weak wells or small pumps is often accumulated in small earthen unlined reservoirs, from which a multiple head is applied to the land at intervals more economically than if the discharge of the well be used directly. The large majority of wells and pumping plants are owned by individuals or neighbors in partnership, there being only a few incorporated companies.

Effect of Salton Sea on Underground Water.

The percolating water which is confined beneath certain strata has its movement directed towards the Salton basin, where before the late inflow of Colorado River the moisture escaped by evaporation from the bottom of the basin. During 1905 and 1906, Salton Sea was so bountifully replenished by the Colorado that the water reached a maximum elevation of 197 feet below sea level and a depth of 76 feet over the bottom of the old salt marsh in February, 1907, when the river was turned back to the Gulf of California. Since that time the water in the newly-formed sea has been lowered by evaporation and the level January 1, 1916, was 237 feet below sea level. The present area of Salton Sea is shown on the map in cross hatch, while the high-water line of 1907 is shown by dotted line.

The effect of water in the Salton Basin has probably been to stay the escape of the underground water percolating toward it and to add to the artesian pressure in Coachella Valley, although due to the overbalance of other influences the artesian pressure has in general diminished since the late formation of the sea.

Maintenance of Salton Sea.

The question of the wisdom of maintaining the present status of Salton Sea has been raised, but it can not be considered with reference to Coachella Valley alone. The land now submerged in Coachella Valley contains over 3 per cent of alkali and is too salty for agricultural purposes. The land in Imperial Valley at the southeast end of the lake that was covered by the high water but from which the water has now receded is good soil, and most of it is now being farmed. As the water recedes the land is being applied for under the Desert Act. During the inflow into Salton Basin in 1905 and 1906 much silt was deposited about the mouths of New and Alamo rivers and as the lake recedes the water line is found to be much different than when the water was rising. The deltas built out have light slope and a small reduction in the gage exposes a large area of land. Some of the area covered was sand dune land. The water leveled the dunes and spread a crust of silt over the sand. The inflow is at present controlled by the Imperial Irrigation District and the mutual water companies of Imperial Valley. Flood waters in Colorado River are prevented from entering the sea through New River by levees in Mexico. Seepage water from Imperial Valley lands and waste water from the irrigation ditches flows to the sea through New and Alamo channels. Much of the waste water, of which most is in the Alamo, is being appropriated

for irrigation of low lands near the sea and the amount of water entering the sea is more likely to diminish than to increase in the future.

The loss by evaporation from the lake has been enough greater than the inflow to lower the water surface at the rate of about four feet per year since the high level of 1907 occurred. In case of accidental break in the Colorado River levees and another season of inflow, it would be desirable for the protection of farm lands in Imperial Valley to have a large unoccupied catchment basin in Salton Sink to receive the water.

The contract for the recent transfer of the Imperial Canal by the Southern Pacific Company to the Imperial Irrigation District provides, among other things, that the district shall not permit water to flow into Salton Sea in excess of an amount that would raise the water level on the railroad lands more than three feet over the highest level of the preceding year. Since the evaporation is now four feet per annum and as the rate will increase as the area becomes smaller, the water is expected to diminish. While jurisdiction over Salton Sea may not lie entirely within this contract, the Imperial Irrigation District is now in better position to control Salton Sea than any but the government. The control should not hinge entirely on value of lands subject to inundation. Salton Sea has an area of 300 square miles. To maintain the present level of the lake would require 768,000 acre-feet of water annually, enough for the irrigation of 256,000 acres of land. As there is more good land on the Colorado than the river will irrigate, it is apparent that the water would have a greater value for producing crops than it would have in Salton Sink.

Lands.

The floor of San Gorgonio Pass, away from the numerous stream channels which cross it, is soil well suited to agriculture and horticulture. The expansive cone or fan sloping southeastward from Whitewater Canyon for several miles, grades from boulders and coarse gravels to gravel and sand. The greater portion of the desert from Palm Springs settlement to Point Happy, including the territory along the railroad, is very sandy and the land is dotted with shifting dunes.

The winds which account for the presence of the dunes sweep down from the higher elevations through the eastern end of San Gorgonio Pass and on across the desert to replace the heated atmosphere of Salton Basin. They are so strong and frequent through the central portion of the desert, especially in the spring season, that the region is unsuited to agriculture and the land along the railroad from Palm Springs station to Myoma can hardly be reclaimed even should there be water for it. The town of Palm Springs and lands below Mission Canyon are remarkably well sheltered, while lands along Whitewater wash, below Deep Canyon and at Seven Palms, are far enough out of the track

Plate V, Fig. 1 (upper).—One of the old pumping plants on the southwest side of Coachella Valley. The old water line is shown on the coral reef in background. Fig. 2 (lower).—Mill Creek Canyon.

of the violent winds to permit profitable cultivation. Below Point Happy the winds expand over the broader and less confined area of the settled portion of the valley where they lose much of their force. A ridge of mammoth dunes parallels Whitewater wash for several miles at Indian Wells and the stream when flowing is confined between them and Point Happy. The sand dune area extends below the point on the southwest side of the valley. The lower limits of the sand dune area are shown on the accompanying map by dotted line.

From Point Happy to Salton Sea most of the valley is below sea level. The ancient beach line is clearly traced on both sides of the valley and is about 40 feet above sea level. The old water line is shown by the photograph, Pl. V, Fig. 1, on the coral reef at the southwest side of the valley. Apparently the alluvium from the canyons and the desert sands transported by wind have intermingled with the delta silts to form the valley soils. The United States Bureau of Soils has surveyed the soils below Point Happy. The central portion of the valley from Indio to Mecca is in the main classed as sandy and fine sandy loam and the lower part next to Salton Sea as clay. Irregular strips along the edges of the valley are sand grading to gravel on the slopes up to the old beach line.

The land now submerged by Salton Sea contains over 3 per cent of alkali. The central portion of the valley from Thermal to the sea and mainly southwest of the railroad contains from 1 to 3 per cent of alkali. A neck of this area also extends up the arroyo from Thermal to Indio on the northeast side of the railroad. The remainder of the valley has less than 1 per cent of alkali, the sandy soil near the old beach line and the dune sand around Point Happy having less than .20 per cent. The area with over 1 per cent of alkali is enclosed on the accompanying map by a dashed line. The land in its natural state supports characteristic growth of the Colorado Desert, salt weed in the lower areas, mesquite along the washes or on the hummocks in soft soil and an occasional palo verde.

The lands were classified as agricultural and nonagricultural by the United States Department of Agriculture in cooperation with the Conservation Commission of California in 1912. The agricultural land is summarized as follows:

	Agricultural land, acres
Coachella Valley, below Point Happy	155,680
Coachella Valley, above Point Happy	7,[illegible]80
Palm Springs	7,680
Desert at Seven Palms	9,[illegible]60
Desert below Mission Canyon	4,480
Morongo Valley	5,120
Eastern slope of San Gorgonio Pass	26,680
Total	196,320

Land Ownership.

Settlement in Coachella Valley was subsequent to the building through of the Southern Pacific railroad in 1879 and the railroad company acquired by grant each alternate section of land throughout the valley, in aggregate nearly half the area. The public land of value below Point Happy has all been filed on under the homestead and desert land acts and most has been patented. The railroad lands were placed on the market a few years ago and over 75 per cent of them below Point Happy have been sold, while those on the desert above are mainly unsold.

At present settlement is extending to the government lands along the wash above Point Happy, where there are numerous pending land entries. Wells are also being bored at Seven Palms, where the topography is favorable to light pumping lifts, and in Morongo Valley. Promoters have in late years colonized lands at Cabazon in San Gorgonio Pass, while a project at the mouth of Palm Canyon failed to materialize. The Banning Water Company was organized in 1884.

The agricultural development in lower Coachella Valley, which began actively about 1900 along the railroad, has been steady, and recent development has extended to the slopes on the southwest side of the valley, where much of the good soil is located. The photograph (Pl. V, Fig. 1) is of the Travis pumping plant at the coral reef. A description of this plant illustrates the character of the larger developments in this region. The well is 12 inches in diameter, 745 feet deep and water stands at 31 feet from the ground surface. The pump is an eight-inch centrifugal and the power a 60-horsepower gasoline engine. The discharge of the pump is given at over five second-feet. The plant is for the irrigation of 320 acres.

The Cabazon, Augustin and the greater portion of the Torros Indian reservations are in lower Coachella Valley and the Agua Caliente is at Palm Springs. Morongo, Mission Creek and Santa Rosa reservations are wholly or partially within the drainage basin. Some of the Indian lands are now inundated by Salton Sea.

The unimproved lands of the railroad company are selling at $35 to $110 per acre. Improved land in the valley is held at $50 to $150 per acre and some planted to date or citrus orchard is held $300 to $600 per acre or higher, in the case of producing date palms on the proper kind of soil.

Crops.

The principal crops in Coachella Valley are alfalfa, wheat, barley, cotton, beans, onions, cantaloupes, grapes, citrus fruits and dates. The places where the date industry gives promise are limited to a few localities with peculiar conditions in the extreme southwest, and none fill the

requirements better. The date palm withstands alkali to a high degree and some orchards are growing on the moist salty lowlands but these do not produce as good quality of dates as the soft sandy soils which take more warmth. The warm soil, together with the long hot season of low humidity, give high percentage of sugar to the fruit and mature such delicate but preferred varieties as the Deglet Noor. The Bureau of Plant Industry of the United States Department of Agriculture conducts an experimental date farm near Indio. The date industry is important as a highly specialized crop with good prospects for profitable extension rather than for large area now devoted to culture, although it is estimated that about 800 acres have been planted to palms.

Climate.

The pronounced features of climate of Coachella Valley are extreme heat in summer, great length of hot season, dry atmosphere, strong winds during late winter or spring, wide range of temperature between noon and midnight, mild winters, low and erratic precipitation, all desert characteristics. The following are the mean maximum and mean minimum monthly temperatures in degrees Fahrenheit at Indio for a period of 14 years prior to 1909:

Month	Mean monthly maximum	Mean monthly minimum
January	67.0	39.7
February	72.9	43.9
March	79.2	51.0
April	87.6	58.2
May	92.5	63.7
June	101.4	71.0
July	107.1	78.8
August	105.3	77.0
September	100.8	70.0
October	90.3	57.8
November	79.5	47.2
December	69.6	38.4
Annual	87.8	58.1

The highest temperature recorded in the full 34-year period for which measurements were made was 125 degrees in July, and the lowest 16 degrees in January.

Area Irrigated.

A canvass of the irrigated land was made by the United States Department of Agriculture in cooperation with the Census Bureau in 1909, and the irrigated tracts as then determined are shown by hatching on the accompanying map. Some of the irrigated land in the valley was overlooked in that canvass, and additions have been made since 1909 so

that the map shows only a part of the lands irrigated at present. The area irrigated below Point Happy as shown by the map is 3,800 acres, whereas it is estimated that 6,000 acres are being irrigated in 1916.

The area irrigated in the entire drainage basin of Coachella Valley is summarized as follows:

Irrigated area	Acres
Coachella Valley below Point Happy	6,000
Coachella Valley above Point Happy	160
Palm Springs	300
Seven Palms	80
Mission Creek Indian Reservation	160
Morongo Valley	160
Whitewater	160
Cabazon	320
Morongo Indian Reservation	1,300
Banning	2,700
Total	11,340

Duty of Water.

But few data on use of water in Coachella Valley are available, but the duty is probably a little higher than in Imperial Valley, where soil, climate and crops are much the same, and where about three acre-feet per acre is used per annum for the entire area. Making allowance for a somewhat more economical use at Coachella on account of most of the water being pumped, than in Imperial, where it is from canals, the duty is estimated at two and one-half acre-feet per acre. The duty of water at Banning, where orchards are irrigated, is found on the basis of the use of 11 second-feet for seven months on 2,700 acres to be 1.7 acre-feet per acre. Assuming a duty of two and a half acre-feet per acre for the total area of 11,340 acres irrigated in the drainage basin, 28,350 acre-feet are used annually from Whitewater River and tributaries.

The ratio of area irrigated to the area of watershed is very low. Considering only the San Bernardino and San Jacinto mountain portions of the drainage, 11,340 acres are irrigated from 523 square miles of watershed. On San Antonio Creek 20,000 acres at Pomona, Claremont, Upland and Ontario are irrigated from a watershed in San Gabriel Mountains of 36 square miles. The two watersheds compare favorably as to elevation, but differ as to rainfall. On San Antonio Creek all surface discharge is used in the irrigating season, the distribution being entirely by underground pipe. The underground water is pumped from over 100 wells and winter flood waters are spread over the gravels to replenish the underground basins so that practically no water escapes.

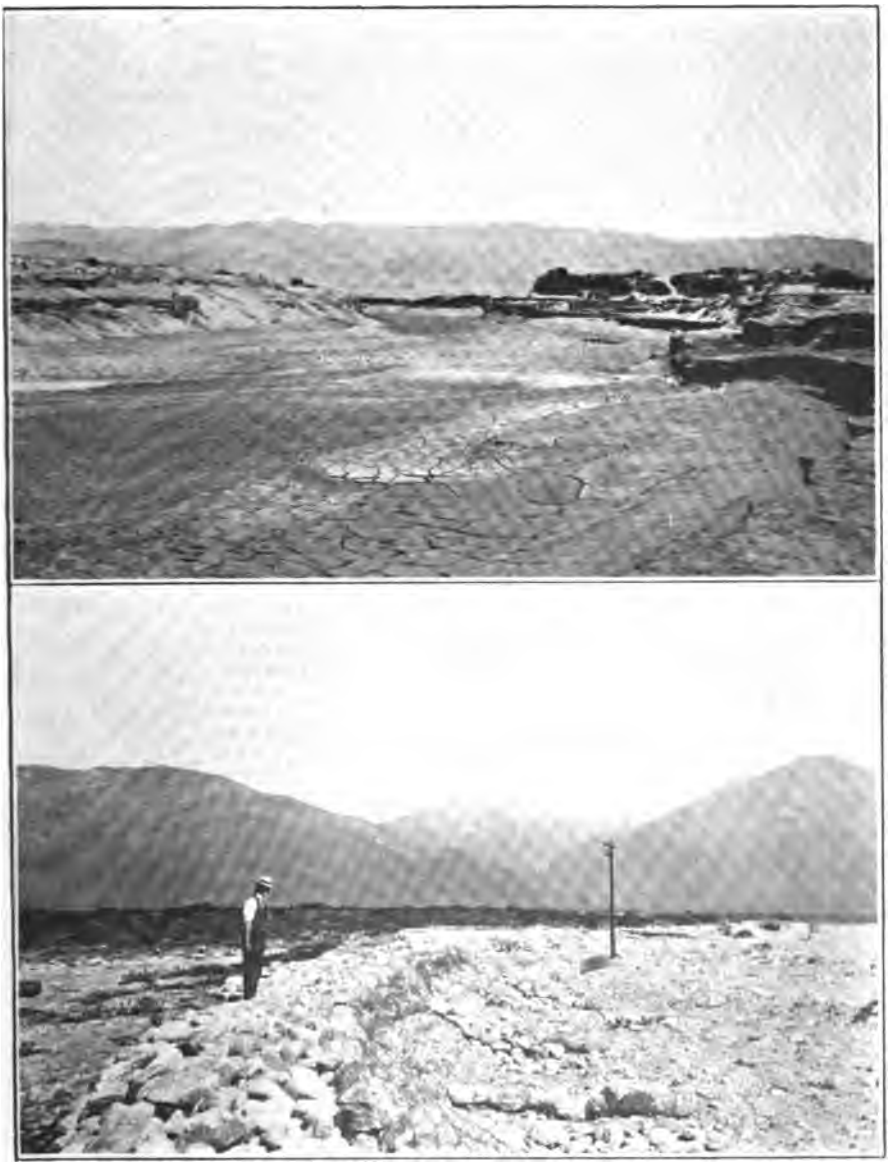

Plate VI, Fig. 1 (upper).—Channel eroded and enlarged by flood of January, 1916, along the location of levee constructed by Indio Levee District. Fig. 2 (lower).—Rock levee on San Antonio Creek. The drift on the face of the levee shows height at which flood water stood.

Conditions are unfavorable for such an efficient use of water from Whitewater River. The stream discharge varies much throughout the year, storage sites are not available, the valley lands are distant from the canyon, piping the water across the desert would be expensive, the evaporation is high, and it is impossible to recover from wells all the water that sinks.

Water Rights.

Water rights are based on appropriation and use while some of the irrigated land in San Gorgonio Pass and at Palm Springs is riparian. Most of the appropriations have ripened into prescriptive rights. So far as is known the courts have not been called upon to decide any water right questions on Whitewater River or as between well owners in Coachella Valley. The valley irrigators opposed the diversion from the Whitewater to Banning by the Consolidated Reservoir and Power Company a few years ago by objecting to the company being given rights of way through the national forests, but the permits were granted and the question of water rights did not reach the courts. In this case the water is not carried outside of the general drainage basin, but its use at Banning must, to a slight extent, lessen the amount reaching Coachella Valley. It is understood that the proposed Pluth power projects for Whitewater Canyon contemplate the return to the stream of any water used.

Waste of Water From Flowing Wells.

Wells in the artesian area near Salton Sea are in some cases allowed to flow when the water is not being used. This practice should be condemned. The law of California requires that flowing wells be capped when not in use. The convenience of the individual must be subjected to the rights of the public and the conservation of the valley's water supply. To equip wells with valves and to close them when the water is not being used is not a burden on well owners, except in some cases where damage to the wells would result. The well and the land may be private property, but the water is the property of the state.

Storm Water Problems.

Whitewater River, after leaving its canyon, is joined by San Gorgonio River. The stream, after crossing the steep slope of its debris cone, is joined by Tahquiz Creek. It is only in times of flood that any water flows on the surface below this junction, but at such times the confluent waters seek the lowest side of the valley, which is above Point Happy, on the southwest side. But near the point the slope changes, and below the point the transverse slope, or that at right angles to the main slope

of the valley, is toward the northeast side. The floor of the valley and desert may be likened unto a warped surface, in which the twist occurs at Point Happy. The main water channel then crosses to the other side of the valley where this change in slope occurs, and in crossing over it is aided by the deflecting force of the point. The channel is not so well defined through the lower valley, and there appears to be two channels along which flood water passes to Salton Sea. One of these follows along the center of the valley, while the other, which is the more pronounced, follows along the lowest level, and after crossing the railroad above Indio leads along the northeast side of the track past Coachella, but recrosses the track at Thermal, and finally terminates in Salton basin.

The first organized effort to control floods was by the Indio Levee District, which embraced only T. 5 S., R. 7 E. This district planned to conduct all the flood water north of and around Indio to the lower channel northeast of the railroad and for this purpose began the construction of a ditch and levee about four miles in length. The location of the levee is shown on the map. The first mile at the upper end of the ditch and levee had been constructed when the flood of this year came.

Flood of 1916.

The flood of January 17, 1916, which is believed to represent the maximum rate of discharge for Whitewater River, came very suddenly. It is noted from the tables of precipitation given herewith that the rainfall for the two days, January 16th and 17th, was, at Seven Oaks 11.70, Beaumont 4.28, and Cabazon 4.40 inches, also that the total rainfall for the 15 days preceding these dates was, at Seven Oaks 5.62, Beaumont 3.53, and Cabazon 0.20 inches. Rains also occurred in the preceding December. The mountain slopes were probably already fairly well saturated at the time of the high precipitation at the middle of January and the two days storm produced a rapid run-off from the steep and rather thinly-timbered watersheds. The travel of the storm, west to east, being the same as the direction of the stream flow, tends to large accumulation of water and sudden discharge.

Whitewater and San Gorgonio rivers, Millard, Snow and Tahquiz creeks and Deep Canyon gave high discharge. The high water reached to Palm Springs in the forenoon of January 17th, and receded towards evening. The flood eroded a large channel, shown by Pl. VI, Fig. 1, across the valley along the Indio levee and overflowed, doing much damage to towns, farms and roads. The county highway was also damaged at many points all the way from Banning to Indio. It will be noted from the map that this road follows near the stream channel almost throughout this distance. Damage also occurred to farm property in the upper valley and at Palm Springs and the Rogers Ditch was

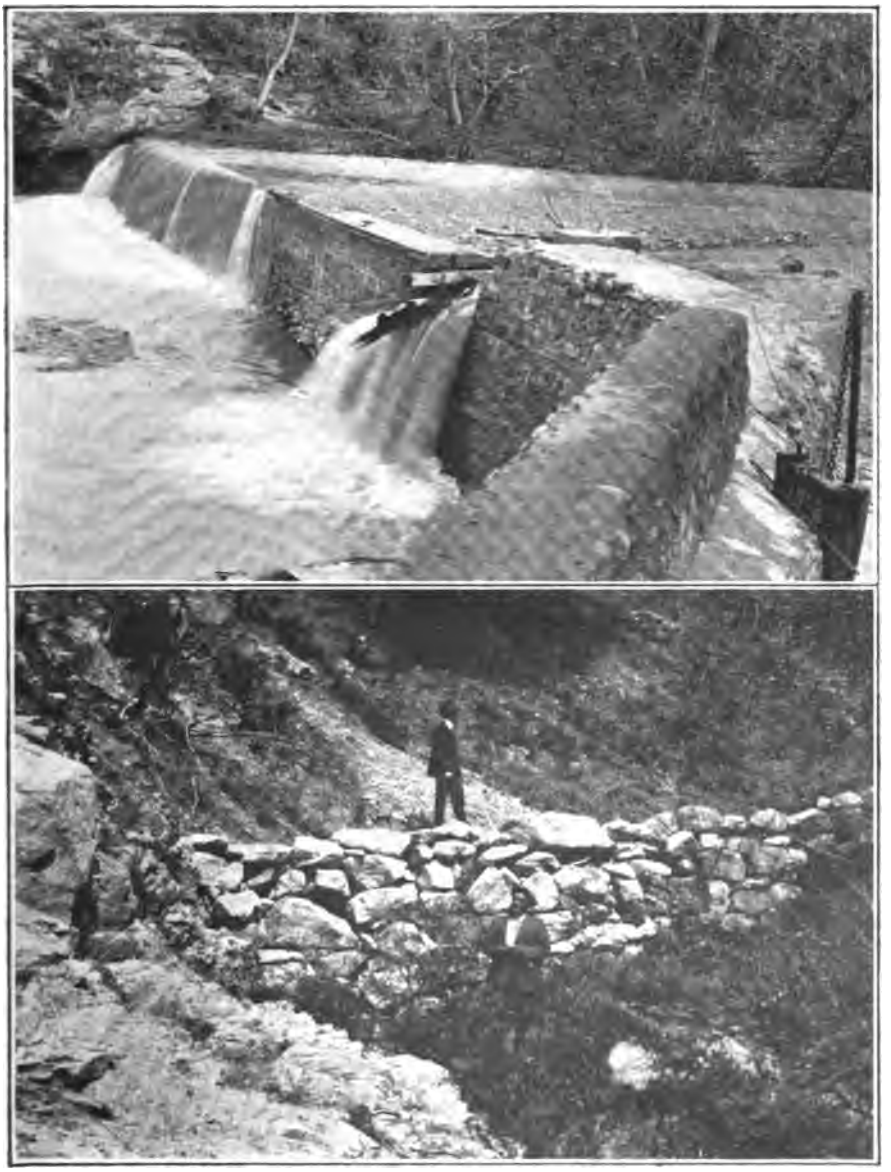

Plate VII, Fig. 1 (upper).—Submerged dam on Santiago Creek. Fig. 2 (lower).—Rock check dam constructed by Los Angeles County in Haines Canyon in experimental flood control.

filled with sand for several miles. The Southern Pacific Company suffered damage to track at the numerous stream crossings between Banning and Palm Springs Station and again from Indio to Thermal.

Coachella Valley Storm Water District.

The plans of the Indio Levee District, had they been carried out, might have safeguarded property at Indio, but they made no provision for protection of lower lands and the Coachella Storm Water District was organized for the lower portion of the valley. It then became apparent that the problem must be solved with respect to the best interests of the entire valley and the Coachella Valley Storm Water District was organized under the law of California, absorbing the two smaller districts and embracing all valley land from Whitewater to Salton Sea. The boundary of the district is shown on the accompanying map in heavy solid line. The district has an area of 169,600 acres, of which about 80,000 acres are non-agricultural. It includes about 28,000 acres of Indian lands on the Agua Caliente, Cabazon, Augustin and Torros reservations and about 30,000 acres of unsold railroad land, of which about 18,000 acres are on the desert above Point Happy.

In a review of methods of disposing of flood water, the following may be considered: Storage in reservoirs; check dams to retard the flow; spreading surplus waters over gravel beds; channel to carry flood water, and levees to protect the lands from overflow. The problem, however, should not be confined merely to the disposal of flood water, but should also take into account the conservation of the water supply and irrigation resources.

Storage in Reservoirs.

No systematic search for reservoir sites in the watersheds of Coachella Valley drainage has been made, but examination of the topographic map fails to disclose any promising locations for dams. The engineers for power companies report that no storage sites were found in the Whitewater watershed. Aside from the question of sites it would be very expensive to conduct stored water from mountain reservoirs across the desert to the agricultural lands.

Check Dams.

Check dams are used in Switzerland, Austria, France and Japan to control floods and to prevent erosion on mountain streams with steep grade, and Los Angeles County is now experimenting with them in Haines Canyon as a means of flood control. Private parties have also constructed small check dams in Ward Canyon, a small stream near Los Angeles, for the protection of an estate. The dams, after being in

use two years, show that they have been very effective in causing the water to be absorbed in the canyons, in prolonging the period of discharge, and in destroying the force of the flood water within the mountain watersheds, and the experiments justify trials of check dams on larger streams with similar conditions. Haines Canyon, according to the report of the Board of Engineers on Flood Control of Los Angeles County, has a catchment area of six and one-half square miles and the discharge in February, 1914, was 712 second-feet per square mile of drainage, being the highest rate of run-off per unit of area of any stream in the county. This exceptional rate is accounted for by all brush in the watershed being burned September, 1913. Check dams to the number of 384 have already been constructed at a cost of $6,000, or $15.62 each. The cost of the dams varied from $5 to $500. An examination of the check dams was made in March, 1916, after the heavy floods of the winter. Pl. VII, Fig. 2 and Pl. VIII, Fig. 2 show two types of dams constructed in Haines Canyon.

A noticeable effect of the dams has been to stimulate the growth of brush, which is proof that the soils along the channels have absorbed more moisture than before the construction of the dams. While it may be reasoned that the method which has been successful in these small canyons can be applied on larger streams by building more and larger dams, it is not considered a practical and economical solution of the Whitewater flood problem. The steep, rocky and barren slopes of the higher mountains would not absorb much water if it were checked and the cost of building a sufficient number of such dams over the large watershed could not be borne by Coachella Valley.

Conservation of Flood Water.

Excellent opportunity is given to spread storm water below Whitewater Canyon for the betterment of Coachella Valley's underground water supply. Such work, besides being a conservation measure, should prevent the smaller floods reaching below Point Happy and should materially lessen the larger floods to be taken care of in the lower valley. In proceeding to consider this method of disposal, it is well to determine the size of the floods and to review what has been accomplished on other streams in southern California. The best place to gage the size of the stream is at Point Happy, for it will be noted from the map that all water is here collected into a single channel and that it is again diffused below the point. The channel near this point is also more confined than on any other part of the stream. The water line of the flood of January 17, 1916, is still apparent on the bank and until a survey of the channel can be made an estimate from observation is offered as follows: Width, 150 feet; greatest depth 15 feet; grade, as

Plate VIII, Fig. 1 (upper).—Head of Coachella Desert where water may be spread over gravels. Fig. 2 (lower).—Check dams built by Los Angeles County in Haines Canyon.

shown by topographic map, 19 feet per mile; character of channel, silt; discharge from Kutter's formula, approximately 9,000 second-feet. As it is possible that the channel erodes at high flood and silts up on a declining stage, it is estimated that the maximum discharge is 10,000 second-feet.

The flow from Whitewater Canyon was probably greater. The river is augmented between the crossing of the railroad and Point Happy by San Gorgonio River, Snow Creek, Tahquiz Creek, Palm Canyon and Deep Canyon, but on the other hand there is loss by absorption in that distance. The point of largest flow is probably just below either the junctions of San Gorgonio River or Tahquiz Creek.

Probably the earliest attempt to store water in the soil by artificial methods for the betterment of an irrigation or water system was work done in Colorado by the Denver Union Water Company over 20 years ago, to increase the flow of a tunnel in Cherry Creek. In Utah, water has been run onto hillside lands, to saturate them in winter, so that the seepage might moisten lower valley lands to the benefit of crops growing there in summer. In southern California the practice of spreading water to increase the output of wells was begun on a small scale on Santiago Creek in Orange County in 1896 and on larger scale on Santa Ana River and San Antonio Creek about 16 years ago. Similar operations have been conducted on Lytle Creek, San Jacinto River, San Dimas Creek, San Gabriel River and San Gorgonio River.

Spreading Water on Santa Ana River.

On Santa Ana River, water is spread over the gravel cone below the canyon between Redlands and Highlands where the slope is from 200 to 50 feet per mile, and in nine reservoirs three to four feet deep and covering about two acres each. The water is diverted from the stream by three permanent main ditches on grades approaching the contours from which it is divided and subdivided and finally allowed to flow from the smallest ditches over the gravelly soil where it is absorbed. The headworks are concrete structures and they are sometimes washed out by the high water and they require frequent repairs while the ditches must receive constant attention while the work is in progress. The work was first done by the Riverside Water Company and the Gage Canal Company of Riverside, but is now conducted by the Water Conservation Association incorporated with membership from three counties representing all of the irrigation interests on the Santa Ana.

It has not been possible to spread the maximum floods and has not been considered desirable to divert water until after the highest water with its detritus has passed as it is believed use at the high stage would silt up ditches and leave the spreading ground less pervious. The

spreading begins two or three days after the peaks of the floods. The association filed claim to 500 second-feet of flood water and the government has withdrawn from entry some of the land in Santa Ana wash for the use of the association, on account of the more general usefulness of the land for spreading than for agricultural purposes. The association owns other lands, giving a total of 2,640 acres for use.

Charles H. Lee, who has made a study of the value of the work on the Santa Ana, states, in the report of the California Conservation Commission for 1912, that the association spread in one year an average of 75 second-feet for 100 days or about 15,000 acre-feet of water at an operating cost of ten cents per acre-foot and a total cost, including interest, of 14 cents per acre-foot. The cost to the association for three years was: Works, $4,371.66; real estate, $2,853; tools, $163.83; operating expenses, $3,619.45, or about $1,200 per year.

The capacity of the system is 250 second-feet. The work requires four men. Mr. Lee, after an investigation of the wells of the San Bernardino basin, concluded that water spreading on an extensive scale had not been conducted long enough to have great effect on the underground water plane and that the rise of the ground water was due primarily to seasons of heavy rainfall but that the water spreading was a commercially practical work of great public benefit.

Francis Cuttle, president of the association, states that the amount of water spread for four years was as follows: 1912, 11,710 acre-feet; 1913, 1,541 acre-feet; 1914, 17,956 acre-feet, and 1915, 13,317 acre-feet. The rate of absorption was 3.22 second-feet per acre for the land and 20 second-feet for the nine reservoirs with aggregate area of 18 acres.

Pl. II, Fig. 2 shows Santa Ana River, at the mouth of the canyon and the head of the gravel cone. Pl. IX, Fig. 1 shows the accumulation of drift after the flood of 1916 had subsided.

Spreading Water on San Antonio Creek.

San Antonio Creek is a smaller stream and water spreading has not been on so large a scale as on Santa Ana River, but the methods have been similar. The mouth of San Antonio Canyon is shown by Pl. X, Fig 2. Proof as to the value of spreading water is perhaps more conclusive on San Antonio Creek than on the Santa Ana. The water is spread over the boulders, gravel and soil below the canyon with slope of 200 to 100 feet per mile. An association has been organized among the water companies and individual well owners, of which there are many in Pomona Valley, to conduct the work, and the cost is borne by the members in the proportion that water is used by them. At first the headworks were of a temporary kind and much work had to be done when the floods came to divert the water. Three main ditches are used. Later

Plate IX, Fig. 1 (upper).—Drift left below Santa Ana Canyon by flood of January, 1916. The diversions of the Water Conservation Association are made just below this point. Fig. 2 (lower).—Division and control gate on ditch for spreading water on San Antonio Creek. The view shows the general character of the spreading ground.

Plate X, Fig. 1 (upper).—Diffusing flood water from San Antonio Creek over porous soil for underground storage by absorption. Fig. 2 (lower).—Mouth of San Antonio Canyon.

concrete headgates were placed on these and a concrete dam was placed across the stream channel at the upper gate. This dam is shown by Pl. XI, Fig. 2 after being damaged by the floods of 1916. Pl. XII, Fig. 1 shows the headgate at the same point. Pl. IX, Fig. 2 shows a division and control gate on one of the ditches and the general character of the spreading ground. A stream of about 30 second-feet is diverted at the upper headgate and less at the lower gates. Streams of 20 or 30 miner's inches are taken from the main ditches and the water is induced to cover as much ground surface as possible. The grades and alignments of the ditches conform to the topography of the land and the more checks to form pools the better for absorption. The association owns most of the land on which it operates. Pl. X, Fig. 1 shows the water flowing over the land on San Antonio Creek. Willis S. Jones, engineer for the association, states that the soil takes up 100 miner's inches or two second-feet per acre continuously during the several weeks of the flood season. A test made by Mr. Jones and the writer shows that the rate of absorption sometimes reaches double that figure. Two men are employed throughout the season and an additional force on occasions. The cost of operation has been 30 cents per acre-foot. The effect of spreading water has been very marked on a tunnel and wells a few miles below the spreading ground. The flow of these increases in the late summer. The effect of the work reaches wells lower in the valley the second year. Except in years of unusual run-off no water is allowed to flow beyond the limits of Pomona Valley.

Spreading Water on Santiago Creek.

The work on Santiago Creek is conducted jointly by the Serrano and Carpenter mutual water companies of Orange County. These companies, one on either side of the stream, secure water from a submerged dam in the canyon and to better their irrigation systems the water must be spread above the dam. Suitable lands for this purpose are found in expanses of the canyon. Systematic spreading of water was begun in 1910 and is now being done on three tracts of land, a total of 400 acres. A maximum of about 100 second-feet of water has been used and the season of work covers three to five months in the winter and spring. The area of spreading is being gradually extended and from $1,500 to $2,000 is being spent annually on ditches, levees and gates. The cost of operation is the wages of one man at $2.50 per day for the season, and wages of two additional men for one month. The method of working on Santiago Creek has differed from that on Santa Ana River and San Antonio Creek. The water is carried in ditches to the spreading ground which is prepared by building levees three feet high on contours 200 to 300 feet apart, depending on the slope. The ends of the levees are turned up the slope slightly to partially basin the water.

The supply stream is led above the upper levee and the water flows around the ends of the levees to lower compartments, its course being directed somewhat by short levees at the ends of the contour levees.

Spreading Water on Lytle Creek.

Flood water is used on Lytle Creek by the Fontana Water Company, of Rialto, and the water must be stored in the canyon to benefit the company's irrigation ditch, which diverts from the mouth of the canyon. The space for spreading in the canyon is so limited that the usual method can not be followed. The method here has been to run water into wells or shafts excavated to depths of about 50 feet. The surface exposed to water in a number of these sumps is sufficient to make the work effective.

Need of Spreading Floods on Whitewater River.

It will not be possible to ingulf all of the larger floods on the debris fans of Whitewater and San Gorgonio rivers and Tahquiz Creek. The work need not be limited by the area as on some other streams, for there is available 9,000 acres between Whitewater River and Mission wash, the 1,200-foot contour and the Southern Pacific railroad, and half the area or 5,000 acres between the railroad and the Rogers Ditch, also half the area or 1,000 acres below Tahquiz Canyon. At the rate of absorption for San Antonio Creek two second-feet per acre continuously, these areas should take up 30,000 second-feet, provided so much water could be handled. Only half of the gravel areas below the railroad are considered, because in flood stage the stream naturally spreads over much of this land.

The work on the Whitewater would of necessity differ in some respects from that on streams in the coast drainage. Nothing is to be gained from either the standpoint of conservation or flood control by spreading water except when the stream would, if uncontrolled, flow below Point Happy. This occurs so few days in each year that the period of diversion would be very short as compared to other streams in California. For the work to be effective during the short high flood periods, a much larger quantity of water must be diverted than has been handled on the other streams. The distributing system of ditches must then be more extensive and costly than those near the coast and a larger force of men must be employed to control the works during these short periods of operation. The infrequent floods in this arid region of erratic precipitation rise so suddenly that a force of men to attend the works would have to be assembled for the flood season each year and a camp maintained at a convenient point. The length of channel above the railroad from which diversions can be made is more limited than the area for spreading above the track.

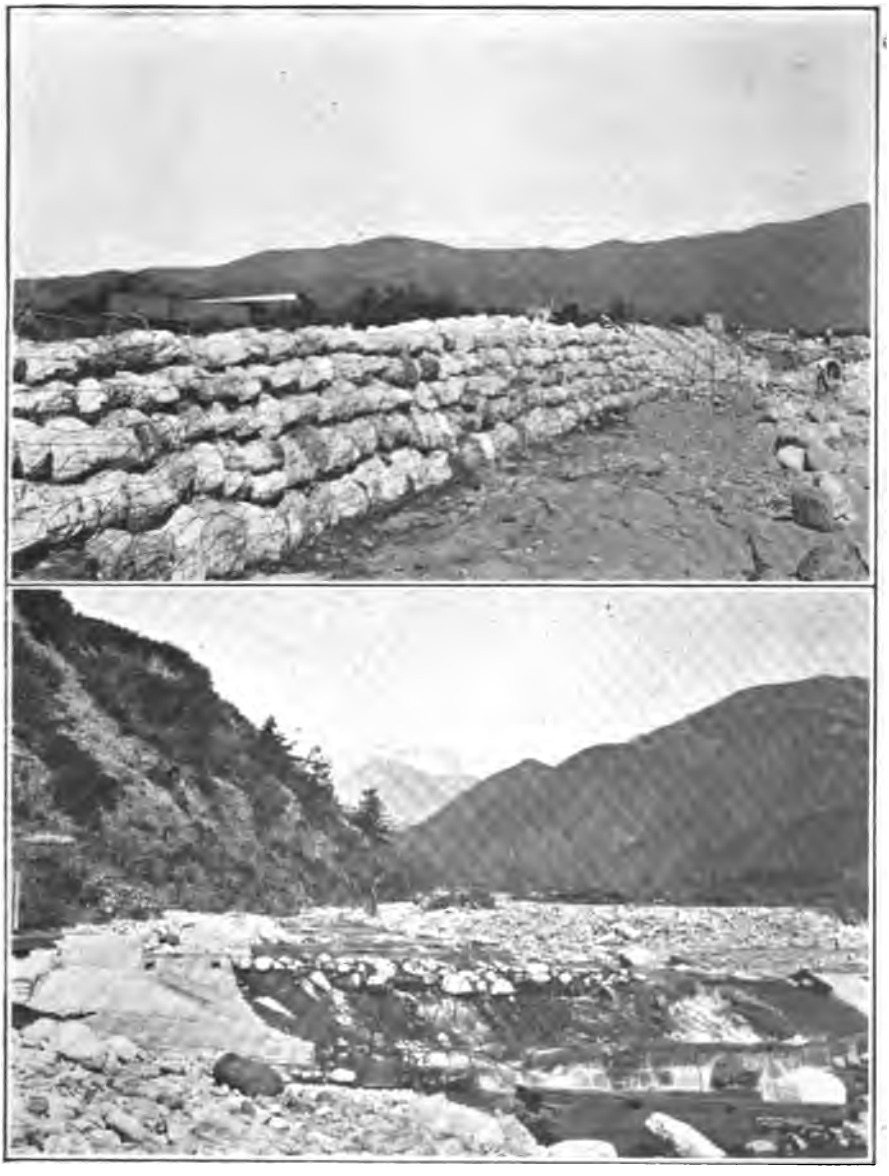

Plate XI, Fig. 1 (upper).—Construction of rock levee faced with boulders enclosed by wire mesh on San Antonio Creek. Fig. 2 (lower).—Mouth of San Antonio Canyon showing damaged concrete diversion dam for spreading water. The view shows the reinforcing rods from which the concrete has been worn away by debris carried by stream.

This case seems to require one of two plans, either massive permanent headworks for taking water out at one or two points, or numerous somewhat temporary dams and headgates, which would require frequent repairs. Unless concrete structures can be made heavy enough to stand the high water, the dams may as well be constructed of boulders, wire and sand bags, to be repaired, sustained or strengthened while the flood is in progress. The weakest point in such a system should be at the head-works rather than in main ditches, for if the latter break, the water would probably damage the railroad at points where bridges are not provided to pass it under the track. Breaks in lateral ditches can be controlled. As it would not serve the purpose of the work to wait until the peaks of the floods have passed, the silt-laden waters would have to be used at risk of detriment to the porosity of the land. The particles of silt, when dry, would be swept by the winds down to the dune lands and the spreading ground left clean for the next season. The action of the wind on this part of the desert is understood when it is known that sand carried by it wears the telephone poles in twain unless they are protected by stubs driven on the west side.

If 2,000 second-feet, or about ten times the maximum rate of use on Santa Ana River be spread for 15 days each year, the total volume is 60,000 acre-feet, a very large addition to the underground water and sufficient for the irrigation of 24,000 acres of land, provided all of it could be recovered. The cost per annum would be $8,400 at 15 cents per acre-foot, the rate on the Santa Ana, including interest; or $18,000 at 30 cents per acre-foot, the rate on San Antonio Creek without interest. Unless 2,000 second-feet can be used, the work will not have much effect on the larger floods.

The mouth of Whitewater Canyon is shown by Pl. II, Fig. 1 as it appeared April 3, 1916. The detritus of boulders will be noted. The suggested locations for ditches for spreading water are indicated by heavy dotted lines on the accompanying map, Pl. I. These correspond to the map contours, but are not located from special surveys.

Ditches for diffusing water need not be true in grade or alignment. They may humor the topography, and the more checks the better. A lower embankment only is necessary. Pl. XI, Fig. 1 and Pl. VI, Fig. 2 show rock levees along San Antonio Creek to control the channel in connection with water spreading. This type of construction is adapted to locations where the rock is at hand. The water face of the levee is protected by a mattress of boulders enclosed by wire mesh tied throughout to prevent the stone accumulating at the bottom and anchored at the top and base. The levee is further protected by stringing sacks of boulders tied sausage-like and anchored at one end only. The design of the levee is shown by the accompanying sketch. A length of 8,000 feet of this levee was built for $2,000.

Need of Flood Water Channel.

As it is hardly possible to prevent all flood water reaching lower Coachella Valley, a channel to confine and direct the surplus water should be located and improved below Point Happy. Even should the upper tributaries be controlled, it is probable that Deep Canyon would at times discharge enough water to reach Salton Sea. Conditions are not so favorable to spreading water at the mouth of this canyon for the stream discharges on the more pervious silt floor of the cienega with its moist subsoil at Indian Wells. The problem now before the Coachella Valley Storm Water District is one in which conservation of the water supply, flood control, best use of water in irrigation, improvement of the highway, and drainage of saturated low lands are interrelated.

The location of the Riverside County highway depends on the route selected for the flood channel. The highway is now being cut through the rock at Point Happy. At present the main road leads to Indio and through the other towns along the railroad. The county is waiting for the storm channel to be located before determining the route of the new road through the valley. The bonds for the road from Banning to the Imperial County line, amounting to $275,000, have been sold and interest is being paid on them. The accompanying map, Pl. I, shows, outlined by dashed line, an area of 27,300 acres with one to three per cent of alkali. Some of this land is being farmed, but much of it would be improved by drainage. A channel running through it may be made a step towards a more comprehensive drainage system, and should be a direct benefit to the land by removing some of the salt. If water be not conserved on the gravel cones the outlook for a large extension in the irrigated area is not good. There is yet plenty of good land on which to use the water now available; however, the most economical pumping is in the low area, and in case of overdevelopment of the underground water the wells in the low area would be affected last, so it is probable that the low lands, except where the salt content is excessive, will always be farmed.

Location of Flood Channel.

Two routes for a flood channel are worthy of consideration. One would be to continue the plan begun by the Indio Levee District by conducting the water north of Indio to the main natural channel through the valley northeast of Coachella and crossing the railroad at Thermal. The other would be to hold the water to the southwest side of the valley below Point Happy, allowing it to enter one of the natural channels in the middle of the valley, towards Salton Sea.

The advantages of the first-mentioned route are that it follows the lowest depression of the valley, and a natural, if inadequate, channel to which most unconfined water gravitates; that it should be easier to

Plate XII, Fig. 1 (upper).—Headgate below San Antonio Canyon near Claremont for water conservation work of Pomona Valley Association. Fig. 2 (lower).—Head of gravel cone at mouth of Santa Ana Canyon January 22, 1916. Powerhouse is shown in distance.

maintain than a channel on higher ground, and that it is well located to act as a drain for the improvement of the alkali lands. The disadvantages are that it is close to the towns of Indio, Coachella and Thermal, and to well improved lands, especially above Indio, that it crosses the railroad twice, and that it is not the most direct route.

The advantages of the last-mentioned route are that it is more direct than by way of Indio and that it avoids proximity to the towns and the railroad. The disadvantages are that it would be more difficult to maintain than the lower route, that it passes through some of the best land in the valley, and that it would, through seepage, aggravate rather than improve the condition of moist low land. There is little choice between the two routes on account of length. The distance from Point Happy to Salton Sea along the southwest side is about 20 miles, and by way of Indio and the arroyo 23 miles.

The several divisions of grade for Whitewater River are as follows:

	Fall, feet	Distance, miles	Grade, feet per mile
Source to mouth of canyon	10,085	20	504.0
Canyon to Palm Springs	950	10	95.0
Palm Springs to Point Happy	870	16	54.4
Point Happy to Salton Sea via Indio	317	23	13.8
Point Happy to Salton Sea via southwest	317	20	15.8

The map shows the grade from the 100-foot contour at Indian Wells to sea level to be: along the Indio levee 17.5 feet per mile, and along southwest side 16.7 feet per mile. The grade of either route is sufficient, and there seems to be no serious abrupt changes in grade in either. There need be no short curves on either route. The long bends on the Indio route should not cause trouble.

In either channel the action of a high-water stage would be to erode and of a declining stage to deposit silt. Drain ditches have been constructed on the east side of Imperial Valley, where the soil and grade are similar, by building two small levees to confine the water and by sluicing a channel between them. A high velocity is desirable if the channel is to be in the main cut below the ground surface, but a moderate velocity is better if the current must act against levee built above the ground surface. The cost of construction should not be much different for the two routes, for while the Indio route is longer it should, being on low ground, not require so high a levee as the other route. The advantage would depend largely on whether one route would require more double levee than the other. A levee on one side only may be sufficient for portions if not all of either route. For the benefit of the moist land the Indio route is much the better. This route should, other things being equal, be more easily maintained. In case of accidental

break in the levee the water would be apt to do damage to the towns and to the railroad. In case of similar accident on the other route it is uncertain what direction the water would take, but it is probable that it would flow eastward and reach towns below Indio. It is probable that the Southern Pacific Company would, for the protection of its operating property, favor the route on the southwest as the railroad would have to bridge the channel past Indio twice. If the water be properly controlled the railroad should not be menaced with one route more than the other. The railroad company has much land in addition to its right of way and its interests are in common with those of the entire valley. The best engineering plan should be followed and adjustments made by properly distributing the costs. The land that would be required for right of way for a drain on the southwest side is better agricultural soil than that along the railroad, but the value of the latter may be influenced by proximity to towns. The flood channel can be more cheaply improved by constructing levees with plenty of space between than by excavating a deeper channel between levees closer together to give the same capacity. While the route along the railroad seems the more favorable, final recommendations can not be made until preliminary surveys are made and more information gathered on the two routes. From an engineering standpoint the water spreading on the gravels should be begun first and then the storm drain to control the surplus could be more intelligently designed, but since the problem is complicated by the location of the highway, the directors of the district may decide to construct the drain first.

Summary of Recommendations.

The following is recommended:

1. Preparations should be made by the Coachella Valley Storm Water District to spread flood waters over the gravel areas below Whitewater and Tahquiz canyons to the extent of 2,000 second-feet, or to the extent of preventing water reaching below Point Happy.

2. Surveys should be made to determine the best location and sizes for ditches for spreading water, the number of diversions that can be advantageously made, the area available for spreading over, the character of headworks required and the cost of the works.

3. Application should be made to the Secretary of the Interior to have withdrawn from entry and reserved for the conservation purposes of the district the public lands where water is to be spread over the gravels. Arrangement should be made with the Southern Pacific Company for the use of railroad lands in the same areas.

4. Application should be made to the State Water Commission for the right to use as much of the flood waters as the district intends to store in the gravels.

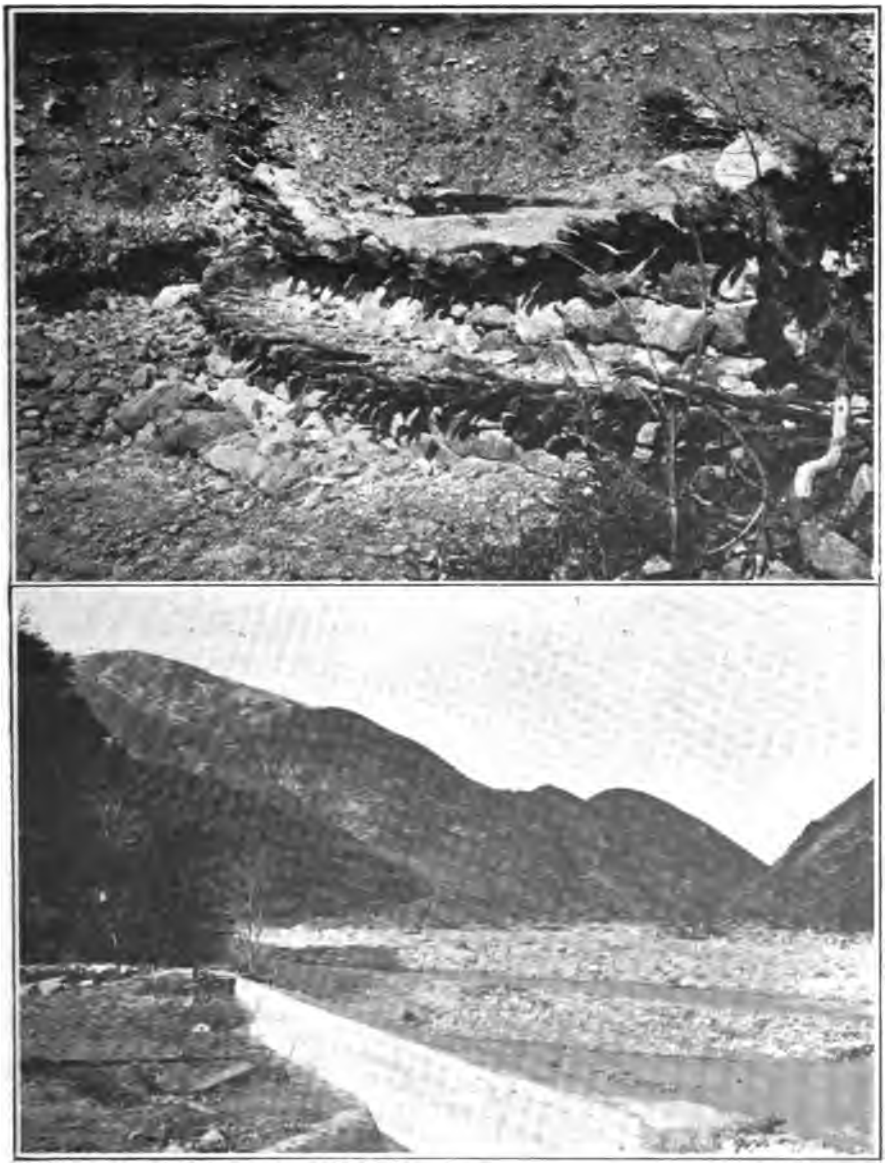

Plate XIII, Fig. 1 (upper).—Rock and brush check dam constructed by Los Angeles County in Haines Canyon. The double crest dissipates the force of the overflow. The dam is depressed where it will concentrate the overflow on the larger rock in the natural stream bed. Fig. 2 (lower).—Lytle Creek at head of Fontana ditch.

5. While the water line of the high flood of January 17, 1916, is still visible, a cross-section should be made of the channel of Whitewater River at Point Happy and the grade determined for one mile past the point from which to calculate the capacity needed in a storm drain in Coachella Valley.

6. Preliminary surveys should be made of routes for a storm drain on both sides of Coachella Valley in order to compare cost and adaptability. The surveys should include determination of the grades and whether a single levee would suffice or whether a double levee would be necessary.

7. The district should, through its organization, aid the district attorney of the county in enforcement of the law for the closing of flowing wells when the water is not in use, except in cases where it is impracticable to close the wells.

Dated May 31, 1916.

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Sixth Biennial Report

OF THE

Department of Engineering

OF THE

State of California

DECEMBER 1, 1916, TO NOVEMBER 30, 1918

CALIFORNIA STATE PRINTING OFFICE
SACRAMENTO
1918

STATE OF CALIFORNIA
DEPARTMENT OF ENGINEERING

Service Banner

Significance of this Banner

The escutcheon commemorates the uniting of democratic nations in a Liberty War for World Freedom, and indicates individual service in that war.

The Shield is an emblem of *Protection*, afforded by a democratic government to its people.

The Paleways: Three pieces, white signifying *Purity of Purpose*, guarded on either side by *Valor*, red.

The Chief: A blue field, representing the nation, supported by Purity and Valor. The color, blue, signifies *Loyalty—Steadfastness—Justice*, meaning that this nation is loyal to its ideals of democracy, steadfast in maintaining its ideals, zealous to secure justice for all peoples.

The stars in the blue field symbolize a new constellation, *Democracy*, appearing in the world's political firmament, a star shining for each nation enrolled in support of democracy on the 6th of April, 1917, when our own glorious Star of Freedom blazed forth as a guiding light to all liberty-loving nations.

Emblazoned on the pale of purity, a red star. The star is an ancient emblem of sovereignty and displayed on the service shield indicates that a *sovereign* of this country has drawn his sword in defense of democracy. The color of the star, red, symbolizes courage. One star displayed for each person serving in the armed forces of the United States.

ALL HONOR

is given to the men of the State Department of Engineering who have joined the colors in the

WAR FOR WORLD FREEDOM

To them is dedicated a SERVICE BANNER emblazoned with a star of valor for each, and in further expression of regard, their names are inscribed upon this

Roll of Honor

Captain HARRY H. BLEE, Aviation Service.
Captain J. BURDETTE BROWN, Engineers.
Lieutenant C. H. KROMER, Engineers.
Lieutenant FRANK E. WOOLDRIDGE, Infantry.
Lieutenant R. S. LAUGHLIN, Infantry, (**wounded**).
Lieutenant C. K. ALDRICH, Engineers.
Lieutenant HARRY H. ARMSTRONG, Engineers.
Ensign HARRY J. DEVINE, Navy.
Student Officer GEO. J. ADAMS, Officers' Training Corps.
Petty Officer P. W. DELONGCHAMPS, Navy.
Sergeant WARD DWAN, Infantry, (**wounded**).
Sergeant RAYMOND NUGENT, Infantry.
Sergeant THOMAS SWEENEY, Engineers.
Sergeant FRANK M. STEWART, Marines.
Corporal HAROLD MCMILLAN, Artillery.
Seaman W. K. DANIELS, Navy.
Private J. G. HEATH, Engineers.
Private W. K. BARTGES, Engineers.

Sixth Biennial Report

OF THE

Department of Engineering

OF THE

State of California

DECEMBER 1, 1916, TO NOVEMBER 30, 1918

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BIENNIAL REPORT OF THE DEPARTMENT OF ENGINEERING.

INTRODUCTION.

In presenting this, the sixth biennial report of the Department of Engineering, it is deemed proper to invite special attention of the Executive and the legislature to certain matters contained herein.

TO OUR DEFENDERS IN THE LIBERTY WAR THE FRONTISPIECE OF THIS VOLUME IS DEDICATED.

Every institution and organization, and well-nigh every family in the land, sent its best sons to the service of our country, and the Department of Engineering is proud of its men whose Service Stars shine forth upon its escutcheon.

Not less is the regard held for others who endeavored to join the colors but failed for reasons that were no fault of theirs. Many offered their services, which were declined, and two were accepted but fell ill on the eve of departure, the armistice being declared before they recovered.

All of those who answered the call were given indefinite leaves of absence with the assurance that their positions would be open for them when they return.

In addition to those who joined the colors, a number of the department's force went into special lines of industrial war work, so that altogether 46 per cent of the male force was released for war activities.

So large a depletion of the working force has necessarily caused some confusion, but the curtailment of building operations by restrictions placed thereon as war measures, and the united efforts of those remaining, have enabled the department to conduct its affairs with a good degree of efficiency.

In this connection it is desired to commend the loyalty of those who remained with the department and who assumed the duties of the missing ones and uncomplainingly performed extra work in order that their absent companions' vacant places should not be filled until the rightful claimants should return.

It is particularly urged upon the Executive and the legislature the desirability of providing means for giving our brave "boys" remunerative employment when they return to their old positions.

Another matter which gives the head of the department much gratification is the patriotic response made by the members of the department to all requests for financial aid in prosecuting the war. The donations to Red Cross, Y. M. C. A. and other war work calls have been generous.

It has been pointed out that the force was greatly reduced by war conditions, yet the department bought $38,950* of Liberty Bonds, being more than 30 per cent of the annual compensation of those purchasing. It should be remembered in this connection that salaries of state employees have not advanced with the high cost of living. Most of them are receiving the same compensation paid them long before the war, when living expenses were scarcely half of the present cost, and with some even the purchase of a small bond meant real sacrifices.

The development of the great valleys of California will probably receive great impetus after the war. Attention is invited to a discussion herein under the title of Conflict of Interests.

It is urged that the Department of Engineering be provided with means to immediately extend its research into matters that will assist in harmonizing warring industries.

It is being proposed in some quarters that the state inaugurate large colonization schemes to provide homes for returning soldiers. In this connection it is urged that if such is to be the policy of the state, close study be made of means of developing some of our vast areas of cheap desert lands.

There is need of careful investigation into proposed irrigation district enterprises, the extent of which is limited by lack of funds.

It is suggested that the Department of Engineering be given a fund for this purpose. It could be largely reimbursed by requiring a district after being organized to pay the expenses incurred.

Attention is invited to a clerical error in section 15*a* of the irrigation district law, as amended in 1917. The error should be corrected.

The cordial relations sustained between the department and the various offices of the state government, the several institutions and the many branches of the federal government with which co-operative work has been conducted, has been a source of personal satisfaction, and the State Engineer takes this opportunity of acknowledging the many courtesies received at the hands of all with whom dealings have been had.

*In addition to this amount $4,450 of bonds were purchased by members away on "war leave," making the total amount $43,400.

PART I.

Sixth Biennial Report of the Department of Engineering of the State of California.

HISTORICAL.

The Department of Engineering was created by an act of the legislature approved March 11, 1907, chapter 183, statutes 1907, and was organized in the May following.

The act creating this department abolished the offices of Commissioner of Public Works, Auditing Board to the Commissioner of Public Works, Department of Highways and State Highway Commissioner, Lake Tahoe Wagon Road Commissioner, and Debris Commissioner, and delegated the performance of their several duties to the Department of Engineering. To the department was also assigned all engineering work for the Board of Harbor Commissioners of San Francisco and the design and construction of buildings and works for all the hospitals, prisons, schools and other state institutions. It was given authority to co-operate with the Department of the Interior and other departments and bureaus of the national government in making surveys, investigations, etc.

Mr. Nathaniel Ellery was appointed to the position of State Engineer and chief executive officer of the Department of Engineering, and assumed the office May 11, 1907. He was succeeded in office by the appointment of Mr. Wilbur F. McClure, incumbent, February 13, 1912.

The records of the organization of the department and the work accomplished by it from the date of its establishment to November 30, 1916, have been published in the reports heretofore issued every two years, and it is the purpose of this report to review the operations of the department during the biennial period just closing.

Since the department was created, each session of the legislature has enacted laws amending the statutes affecting the work of the department, the most notable of which have been the placing in the department the supervision of the design and construction of dams; the examination of proposed irrigation district projects and the supervision, with the bond commission, of the issue of irrigation district bonds thereunder; the administration of the state highway acts involving the expenditure of $33,000,000 for the construction of the state highways.

DEPARTMENT OF ENGINEERING.

Under the statutes now in force the Department of Engineering is composed of two bodies: Advisory Board and Executive Force. These two bodies are constituted respectively as follows:

THE ADVISORY BOARD.

Governor, ex officio member and chairman.

General Superintendent of State Hospitals, ex officio member.

Chairman of Board of State Harbor Commissioners of San Francisco, ex officio member.

State Engineer, appointed by the Governor, ex officio member.

Three members, appointed by the Governor.

The Advisory Board is the administrative head, and directs the operations of the department through the State Engineer, who is the chief executive officer of the department.

The ex officio members receive no salary as members of the Advisory Board. The three last-named appointed members of the Advisory Board are delegated as a special executive committee of the board to administer the state highways, and bear the title of State Highway Commission. These members are paid salaries.

EXECUTIVE FORCE.

This body is composed of two classes of employees, which for convenience are designated as "statutory" and "nonstatutory" employees. The first-named class are those enumerated by the laws which authorize the Department of Engineering to appoint the following:

Highway Engineer.
Chief Engineer for the Board of State Harbor Commissioners (San Francisco).
Two Assistant Engineers.
Secretary.
State Architect.
Assistant State Architect.
Auditor.
General Superintendent for the Architectural Division.
Mechanical Engineer.
Structural Engineer.
Electrical Engineer.
Architectural Designer.
Three Architectural Draftsmen.
Engineer's Draftsman.
Estimator.

Specification Writer.
Blueprint Pressman.
Two Clerks.
Two Stenographers.
Janitor.

These, with the State Engineer as Chief Executive Officer, comprise the "statutory" force. Their salaries are paid from the fund created by the "General Appropriation Act."

The field of operations of the Department of Engineering is so extensive and its activities so varied that the above-enumerated statutory force is not sufficient to properly conduct the work of the department and must be augmented by additional assistants appointed from time to time as exigencies arise requiring their services. Their compensation is paid, usually, from the appropriations made to cover the particular work for which they are engaged. When no such appropriation exists they are paid from the department's contingent fund.

The force of "nonstatutory" employees includes engineers and architects, designers, draftsmen, inspectors, etc., engaged in building operations; engineers, surveyors, inspectors and others required to design and construct waterworks and sewerage plants, etc., at the state institutions; engineers, surveyors, hydrographers, boatmen, foremen, cooks and laborers employed in control and improvement of river channels; engineers and special examiners to investigate bridges, dams and irrigation projects, together with an army of people engaged in the varied operations of the Highway Commission.

DUTIES OF THE DEPARTMENT.

The above list of employments indicates to some extent the varied nature of the department's activities and the extent of the field covered by it. Its duties, as specified by several statutes, are summarized as follows:

To make plans and specifications for all buildings at the various state institutions, to let contracts for and superintend their erection, or, in case satisfactory contracts can not be made, to construct the buildings by day labor. To design and install all heating, lighting, ventilating, refrigerating, water supply, sewerage, and mechanical plants of every nature—whether changes, extensions or original. Survey grounds, lay out walks, drives and roads; provide water supply, irrigation, reclamation, sewer and drainage systems, requiring the design and construction of dams, reservoirs, pipe lines, wells, pumping plants, ditches, sewage treatment and disposal plants and drains.

Design and construct works for the protection of river levees, preservation of navigation and protection from floods.

Conduct research looking to the reclamation of the overflow basins and to effect flood control on the Sacramento and San Joaquin and other rivers of the state.

Studies of the feasibility of navigable canals and canalization of rivers.

Through the engineering force assigned to the Board of Harbor Commissioners, to design and direct the construction of wharves, piers, buildings and their equipment on the water front of San Francisco.

Through the Highway Commission the construction and maintenance of the state highways authorized by the state highway bond acts, and the improvement, repair and maintenance of more than 600 miles of state roads in the mountains.

By co-operation with the federal government a topographic survey of the state is being made; daily measurements are made of the water flowing in all the principal and many of the minor streams of the state; studies of possibilities for developments of power in the mountains and irrigation in the plains. Investigation of the quantity of water required for various crops, methods of applying it, waste in the use of water, etc.

This department is required to co-operate with the engineers of the War Department in matters concerning debris control, flood control and aids to navigation.

Supplemental to the investigation of stream flow for flood control and utilization, the department is engaged in the determination of water stored in the great snow fields of the mountains and the study of meteorological phenomena affecting the run-off.

The State Engineer is required to investigate and pass upon the feasibility of the enterprise before an irrigation district can be organized, and as a member of the District Bond Commission approve plans and determine the cost of proposed works as bases for bond issues as well as the validation of bonds when issued; to keep a general supervision of construction of irrigation works executed under bond issues. Also to perform the same offices in connection with the issue of bonds by county water works districts.

He is ex officio a member of the State Water Commission, which body has control of all water appropriations and the ascertainment of water rights. He is also a member of the Carey Act Land Board.

The State Engineer is required by law to direct the engineering investigations for the Reclamation Board to determine the proper location and sufficiency of proposed reclamation works, so that they shall conform to the plan for the flood control adopted by the state.

Plans for all bridges to cross navigable streams are required to be approved by the State Engineer before they are permitted to be erected.

The law directs that he shall pass upon the plans, specifications and estimates of all dams constructed in the state.

In addition to the active duties enumerated above, the department conducts an extensive correspondence, answering queries from all over the country seeking information in regard to the extent of drainage, reclamation, irrigation and power developments, and many other lines of progress in the state, and the costs thereof. If the information is at hand or can be obtained it is always furnished. This is done upon the theory that all public offices should be in a measure publicity bureaus, and the dissemination of correct information as to the resources of the state and its advantages is a proper function of all branches of the government.

The department has been called upon by municipalities for advice in regard to sewage disposal; by communities asking for the examination of dams, as to their stability and safety, and specifications to strengthen the same, as well as advice regarding flood protection and stream control in different portions of the state. While these are not duties enjoined by law upon the department, the State Engineer has always responded to such requests and given such assistance in an advisory way as the department was able to furnish, and it is gratifying to know that such aid has been regarded of value by the recipients.

Since this country became involved in the great world-war, the State Engineer and the department have been called upon by state and federal officials for aid in matters connected with the prosecution of the war. Such work as the department can do is placed ahead of any other and its best energies utilized whenever called upon.

ORGANIZATION.

As previously stated, the department is divided into branches to handle each different kind of work. These branches are termed bureaus. The executive head of each bureau is called the director. He reports directly to the State Engineer.

The bureaus as now established are as follows:

I. General Office Bureau.
II. Bureau of Architecture.
III. Bureau of Economics.
IV. Bureau of Highways.

I. The General Office Bureau conducts the business of the department relating to all other branches, such as keeping the records and

archives, accounts, contracts, claims and payments, legislation, janitor and messenger service, etc.

II. The Bureau of Architecture, as its name implies, designs and constructs all state buildings.

III. The Bureau of Economics has charge of all matters pertaining to hydraulics, such as irrigation, stream measurement, flood control. reclamation, drainage, and navigation.

Plans for water supply, for sewerage, irrigation, drainage and reclamation, roads and bridges, topographic surveys of grounds and surveys of land boundaries for all state institutions are entrusted to this bureau.

Supervision of dams and bridges is exercised through this bureau.

This bureau also has charge for the state of co-operative topographic surveys, hydrology, meteorology and irrigation investigations, debris control and inland navigation.

IV. That branch of the department designated herein as Bureau of Highways was created for the purpose of carrying out the highway bond acts.

This duty it has performed since 1911. In 1917, since the last report of the department was published, the office of state roads (having charge of the mountain roads) was transferred to this bureau.

The Highway Bureau has so large a task, requiring such a complete organization for one specific purpose, that it almost constitutes a separate department. It is, however, a part of the Department of Engineering and is administered through the direction of members of the Advisory Board delegated to that duty.

PERSONNEL.

At the date of this writing, November 1, 1918, the Department of Engineering is organized as follows:

ADVISORY BOARD.

William D. Stephens.....Governor (Chairman)
W. F. McClure.....State Engineer
Arthur Arlett.....President State Board of Harbor Commissioners
F. W. Hatch.....General Superintendent of State Hospitals
N. D. Darlington (chairman), Chas. F. Stern, ——— ———*.....State Highway Commission

EXECUTIVE OFFICE.

NOTE.—Those whose names are followed by the letters (O. L.) are on leave serving with the colors. The letters (W. W.) following names indicates that the persons are on leave engaged in "war work" other than with the armed forces.

Title	Name	Entered service
State Engineer	W. F. McClure	Feb. 12, 1912
Secretary	Earle Freeman	Mar. 13, 1912

*Henry J. Widenmann, died October 5, 1918.

GENERAL OFFICE BUREAU.

Secretary of Department.....Director

Title	Name	Entered service
Division of correspondence—		
Secretary, chief.		
Stenographer	Lucy K. Adams	April 1, 1912
Stenographer	Henrietta Burt	May 16, 1913
Stenographer	Elsa Koch	Mar. 25, 1914
Telephone operator	Florence Lombard	Jan. 20, 1917
Messenger	Robert E. Hays	Dec. 31, 1917
Division of accounts—		
Auditor, chief.		
Auditor	J. H. Clarke	Nov. 11, 1911
Filing clerk	Chas. Johnston	July 8, 1907
Filing clerk	J. C. McCalmont	Mar. 26, 1912
Clerk	A. J. Adams	May 28, 1909
Clerk	Thos. McCully	Feb. 1, 1916
Clerk	F. M. Stewart (O. L.)	July 28, 1916
Clerk	N. E. White	April 15, 1912
Clerk	C. E. Thorp (W. W.)	Nov. 10, 1917
Clerk	J. W. Hickey	Oct. 17, 1917

BUREAU OF ARCHITECTURE.

State Architect ..... Director
Assistant State Architect ..... Superintendent

Title	Name	Entered service
Director's office—		
State Architect	George B. McDougall	Aug. 22, 1913
Assistant State Architect	Jas. S. Dean	Aug. 1, 1912
Clerk	Harold McMillan (O. L.)	Oct. 1, 1914
Blueprinter	Frank Butler	April 1, 1912
Architectural division—		
Assistant State Architect, chief.		
General inspector	J. W. Dutton, Jr.	Oct. 1, 1912
Chief architectural designer	Chas. F. Dean	Sept. 23, 1911
Architectural designer	R. E. Backus	Sept. 1, 1912
Architectural designer	A. R. Widdowson	July 17, 1911
Specification writer	C. K. Aldrich (O. L.)	Mar. 13, 1914
Estimator	I. C. Satterlee	July 17, 1914
Assistant estimator	Ward Dwan (O. L.)	Nov. 1, 1917
Chief architectural draftsman	Geo. J. Adams (O. L.)	Aug. 15, 1915
Architectural draftsman	Don M. Clippinger	May 15, 1918
Architectural draftsman	W. K. Daniels (O. L.)	Aug. 1, 1915
Architectural draftsman	P. W. DeLongchamps (O. L.)	Aug. 11, 1913
Architectural draftsman	H. J. Devine (O. L.)	Aug. 2, 1917
Architectural draftsman	E. Field (W. W.)	Aug. 1, 1917
Architectural draftsman	J. G. Heath (O. L.)	Feb. 1, 1913
Architectural draftsman	Walter J. Long	Nov. 12, 1912
Architectural draftsman	Carleton Pierson	Jan. 20, 1913
Architectural draftsman	C. E. Richardson (W. W.)	May 6, 1918
Architectural draftsman	Fred Ruckh (W. W.)	Mar. 17, 1914
Architectural draftsman	Leroy F. Sherwood	Jan. 1, 1913
Architectural draftsman	C. F. Strothoff	Aug. 2, 1917
Engineering division—		
General superintendent, chief.		
General superintendent	Luppe B. Luppen	Aug. 1, 1912
Structural engineer	Clarence H. Kromer (O. L.)	Feb. 16, 1913
Structural draftsman	Wm. K. Bartges (O. L.)	June 1, 1914
Structural draftsman	H. A. Smith (W. W.)	July 19, 1917
Structural draftsman	W. Wakeman (W. W.)	Feb. 2, 1918
Mechanical engineer		
Mechanical draftsman	A. L. Burleson (W. W.)	May 2, 1918
Mechanical draftsman	W. H. Epperson (W. W.)	Dec. 26, 1917
Mechanical draftsman	J. B. Hawley	July 12, 1915
Mechanical draftsman	C. A. Henderlong (W. W.)	April 28, 1914
Mechanical draftsman	E. H. Hogan (W. W.)	Mar. 4, 1914
Mechanical draftsman	M. W. Hulse (W. W.)	July 27, 1917
Mechanical draftsman	L. E. Rushton (W. W.)	July 6, 1915
Mechanical draftsman	P. H. Steiner (W. W.)	Oct. 19, 1914
Electrical engineer	G. M. Simonson	Sept. 22, 1913
Electrical draftsman	Andrew Eliason (W. W.)	Feb. 18, 1918
Electrical draftsman	F. H. Saeger (W. W.)	May 16, 1918
Electrical draftsman	Geo. N. Sargent	Aug. 1, 1917
Electrical draftsman	C. G. Zschockelt	June 30, 1915

BUREAU OF ECONOMICS.

Assistant State Engineer.....Director

Title	Name	Entered service
Assistant State Engineer	Paul M. Norboe	May 17, 1907
Flood control and reclamation division—		
Assistant State Engineer, chief.		
Flood control engineer[1]	E. A. Bailey	June 1, 1912
Navigation division—		
Assistant State Engineer, chief.		
Chief engineer, San Francisco harbor[2]	Frank G. White	July 7, 1916
Hydrographer	Harry H. Armstrong (O. L.)	[3]June 26, 1918
Hydrographer	J. B. Brown (O. L.)	Feb. 1, 1916
Superintendent, river work	Clifford P. Childers	May 15, 1912
Foreman, river work	Raymond Nugent (O. L.)	Aug., 1914
Foreman, river work	Frank E. Wooldridge (O. L.)	Sept. 1, 1909
Clerk	Thomas Sweeney (O. L.)	April 20, 1914
Boat engineer	Orland W. Wallace	May 15, 1912
Helper	Harry Wicks	Dec., 1917
Cook	Hom Wo[4]	Nov. 2, 1914
Irrigation division—		
Assistant State Engineer, chief.		
Project examiner	W. L. Huber[5]	Occasional
Division of co-operative research—		
Assistant State Engineer, chief.		
U. S. Geological Survey—		
Topographic	George A. Davis	----------
Hydrographic	H. D. McGlashan	----------
U. S. Department of Agriculture—		
Irrigation inquiry	Frank Adams	----------
Division of institutional service—		
Assistant State Engineer, chief.	S. W. Curtis	Nov. 21, 1916
Engineer	Augustin J. Beakey	June 10, 1912
Engineer's draftsman	Edward D. Nickerson	April 18, 1914
Engineer's assistant	R. S. Laughlin (O. L.)	July 2, 1917
Engineer's assistant	Fred W. Hatch, Jr.	Dec., 1915
Road division[6]—		
Road engineer	Harry H. Blee (O. L.)	April 10, 1913

[1]Assigned to duty with State Reclamation Board.
[2]Appointed Chief Engineer, San Francisco Harbor Commission, succeeding Jerome K. Newman, July 7, 1916.
[3]Transferred from Reclamation Board.
[4]Native American of Chinese parentage.
[5]Occasionally employed for special occasions.
[6]Office transferred to highways July 15, 1917, after Captain Blee received his commission.

The foregoing lists of employees constitute the permanent force required to conduct the ordinary routine work of the department, but does not include temporary appointments made in the several divisions at times when the work accumulates to a degree that can not be expeditiously disposed of by the regular force.

STATE INSTITUTIONS.

The state institutions for which the services of the Department of Engineering are required under the law, are as follows:

Educational.

Chico State Normal School.
Fresno State Normal School.
Humboldt State Normal School, Arcata.
Los Angeles State Normal School.
San Diego State Normal School.
San Francisco State Normal School.
San Jose State Normal School.
Santa Barbara State Normal School of Manual Arts and Home Economics.
San Luis Obispo State Polytechnic School.

Eleemosynary.

California School for the Deaf and the Blind, Berkeley.
Industrial Home of Mechanical Trades for Adult Blind, Oakland.
Pacific Colony, School for Feeble Minded (Authorized, not commenced).

State Hospitals.

Agnews, Agnew, Santa Clara County.
Mendocino, Ukiah, Mendocino County.
Napa, Napa, Napa County.
Norwalk, Norwalk, Los Angeles County.
Southern California, Patton, San Bernardino County.
Stockton, Stockton, San Joaquin County.
Sonoma State Home (for feeble-minded children), Eldridge, Sonoma County.

Punitive.

State Prison, Represa, Sacramento County.
State Prison, San Quentin, Marin County.

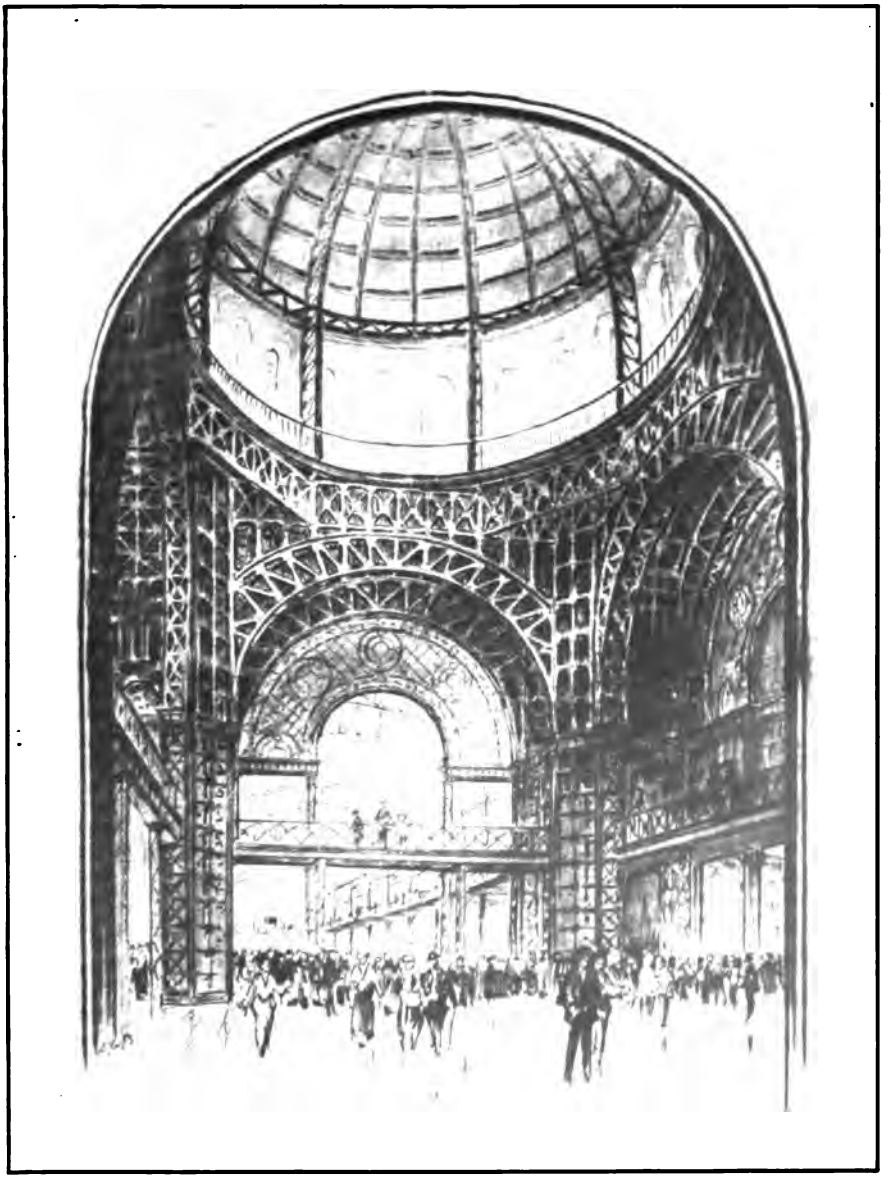
Reformatory.

Preston School of Industry, Ione, Amador County.
Whittier State School, Whittier, Los Angeles County.
California State School for Girls, Ventura, Ventura County.

Military.

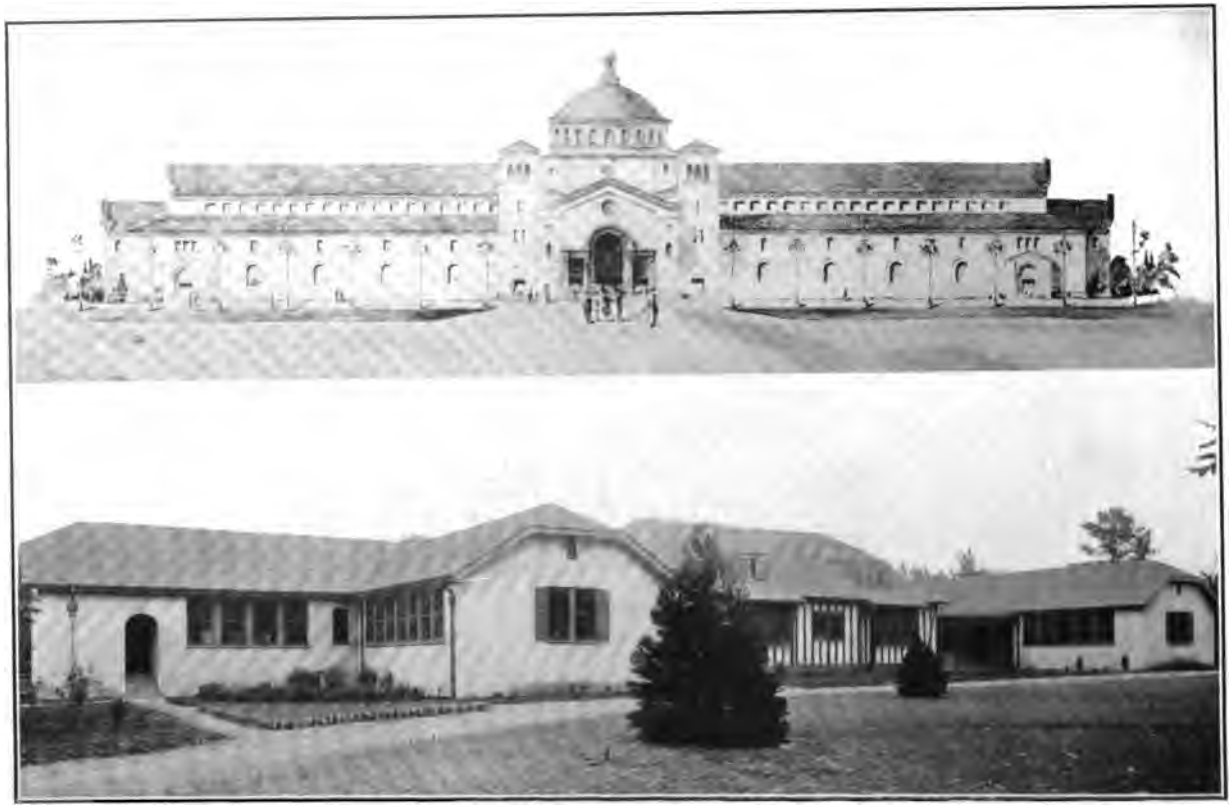
Veterans' Home, Yountville, Napa County.
State Arsenal and Armory, Sacramento.
State Armory, San Francisco.
State Armory, Los Angeles.
State Armory, Stockton.
State Armory, Naval Militia, San Diego.

PLATE I.



Exhibition Pavilion, interior, State Fair.

PLAT E II.



Upper figure, Agricultural Pavilion, State Fair.

Lower figure, Infirmary, Napa State Hospital.

Miscellaneous.

State Capitol, building and grounds, Sacramento.
Governor's Mansion, Sacramento.
State Printing Office, Sacramento.
State Fair, buildings and grounds, Sacramento.
Sixth District Agricultural Fair, Los Angeles, buildings.
Sutter's Fort, buildings and grounds, Sacramento.
Marshall's Monument, building and grounds, Coloma.
California Redwood Park, buildings and grounds, Santa Cruz County.
Women's Relief Corps, buildings and grounds, San Jose.
Harbor Front, wharves, piers and buildings, San Francisco.
Mission Solano, Sonoma County (restoration).
Old Russian Church, Fort Ross (restoration).
Monterey Custom House and Old Theatre (restoration).
State Fish and Game Commission, Hatcheries.
State Mining Bureau, Buildings at Taft and Coalinga.
Los Angeles Exposition Building.
State Office Buildings, Sacramento (authorized, not commenced).
State Office Buildings, San Francisco (authorized not commenced).

Architectural Service at State Institutions.

All work of the department pertaining to state buildings, whether relating to the preparation of plans and specifications, or erection and installation, including mechanical plants of every kind, is executed by the architectural bureau of the department, and a review of the work accomplished by that bureau will be found under the report of the State Architect.

Engineering Service at State Institutions.

Whenever improvements are contemplated at an institution, whether it be a new building, or whether water pipes, sewers, walks or drives are to be installed or extended, the first thing needed is a topographic map, showing the location of existing buildings and all the natural and artificial topographic features of the grounds. To meet this demand the department has from time to time executed surveys at several institutions and constructed maps thereof, so that now the department possesses such maps of many of the state institutions Lack of funds, however, has prevented the prosecution of these surveys for all institutions. The absence of data furnished by such maps is keenly felt whenever the architects are called upon to design a new building, as its location and surroundings control or, at least, suggest the type of architectural appearance to be given to the building. The engineers who design the heating, water supply and sewage are greatly aided in their studies by accurate maps. The proper location of roads, drives and walks, and the arranging of scenic effects by the landscape artists are

also better done when access is had to such data. The department has continued this line of work whenever funds were available and it is hoped that it soon will be able to make such maps of all institutions not yet surveyed and to bring those already made up to date.

Agnews State Hospital.

Drainage. The question of draining certain marsh lands at this institution has been discussed and recommended in former reports of the department. By a properly installed drainage system the productiveness of many acres would be greatly increased. During this year a start was made with a field at the north of the institution and about 1500 feet of open ditch constructed. This will carry off much surplus surface water, but to be fully effective should be supplemented with a complete system of lateral drains, preferably tiles.

Mendocino State Hospital.

Water Supply. The source of the water supply for this institution is a creek in the hills back of it. A stone masonry dam 27 feet high was constructed in the canyon several years ago, impounding about 8,000,000 gallons of water which is conveyed in a pipe to the hospital some 2½ miles away.

Within recent years this department has renewed the pipe line, and constructed another dam about half a mile up the creek from the old one. This dam, 63 feet high, built of concrete, creates a reservoir having a capacity of about 45,000,000 gallons. It was completed in the summer of 1916, and the reservoir has been filled each winter since, but as the creek does not flow in the summer, the storage of both reservoirs is barely sufficient for the needs of the hospital. During the summer just past, it being an abnormally dry season, the creek ceased to flow much earlier than usual, necessitating a lengthened period of draft upon the stored supply. The population of the institution was also increased by the assignment of many insane from the army and navy. As a consequence of the concurrence of circumstances named, the reservoirs were depleted before the rains came and resort was had to pumping from wells. A pipe line was laid from a well on the stock farm some 7000 feet to the hospital and the water pumped into an elevated steel tank. By this means and the practice of economy of use the water supply was made to suffice.

The experience of the past season indicates clearly that if the demands for water are to be allowed to increase, it will be imperative to obtain additional water at a very early date.

Napa State Hospital.

Water Supply. The water for domestic use and irrigation is obtained from three sources, viz, a storage reservoir in a canyon above the institution, from Spencer Creek and from wells on the grounds. This year a fourth supply was added.

The dam making the reservoir, which is called by the people at the hospital Lake Marie, was constructed several years ago. In 1916 it developed a leak which caused some alarm to the hospital management. An engineer from the department investigated it and concluded that no danger of failure impended. The water had been drawn down four feet below the full flow line at which point the leak ceased. It was decided that when the reservoir should again be filled and the leak started, exploratory excavations would be made to trace the escaping water to its origin, but unfortunately there has not been sufficient water to fill it.

The suffering of the inmates from insufficient water was quite marked in 1916, and led this department to recommend that steps be taken at once to secure an additional supply. The recommendation was met by an appropriation of $75,000 by the legislature in 1917, for that purpose.

The state owns a large tract of land in Napa Valley east of Yountville, known as the Fry Ranch. Rector Creek, a perennial stream with a minimum flow of more than 600,000 gallons a day, runs through the ranch and discharges into Napa River. Some years ago this department laid a pipe line conveying about 100,000 gallons a day of this water to the Veterans' Home at Yountville.

This source was selected for an auxiliary supply for the Napa State Hospital. A concrete diverting dam was constructed in the creek near the mouth of the rocky canyon and a pipe line laid to the hospital. The pipe is a wire-wound redwood stave pipe 10 and 6 inches internal diameter and 13½ miles in length. It is designed to resist heavy pressures and in places sustains a static head of 350 feet. The pipe was completed and began delivering water to the institution July 7 of this year, at the rate of 300,000 gallons a day.

The acquisition of this new source of water will provide an ample supply to meet the growing needs of the institution for some years.

The Tide Land Reclamation. The reclamation of 380 acres of tide lands along the Napa River, as related in previous reports has proved very effective and has added a large area to the productive farming lands of the hospital.

To further improve its productivity it was recommended in the last report that drainage be provided for the lowest portions where storm water run-off accumulates. This has now been accomplished by the construction of a system of dikes and ditches, and the installation of automatic tide-gates in the levees, supplemented by a small pumping plant to pump out the water accumulating below the influence of the tide gates.

Fry Ranch. This property was purchased by the state some years ago for a specific purpose, which purpose was later abandoned. It con-

tains several hundred acres of very productive agricultural land, a portion of which is planted to alfalfa. It is now being used by the Napa State Hospital as a farm for the growing of produce for state institutions.

The water supply for domestic use is obtained from Rector Canyon Creek which traverses the property as described in the above discussion of additional water for the Hospital.

In conjunction with the work of constructing a pipe line from Rector Canyon to Napa State Hospital, the supply of domestic water to the Fry Ranch buildings was improved by constructing a 6-inch wood pipe about a mile long connecting the hospital pipe and the buildings of the ranch. The pressure at the fire mains is 130 pounds. It has already proved its worth in saving the buildings from fire this past summer.

A plant operating a 4-inch centrifugal pump was installed this year to pump water from Napa River to irrigate alfalfa in a field contiguous to the stream.

Sonoma State Home.

Water Supply. The water for domestic use at this institution is obtained from several springs in the wooded ravines of the hills in the western portion of the estate. The water, which is of most excellent quality, is conveyed in iron pipes to two concrete tanks of about 1,000,000 gallons capacity each, situated on a hill about 150 feet in elevation above the grounds of the home. From these tanks it is distributed to the buildings and grounds. One of these tanks developed serious leaks, which were attributed to earthquake shocks, and for some years has not been used.

For many years the springs furnished sufficient water for domestic purposes and also for irrigating the lawns, but with an increase in population the supply became inadequate.

In 1910 the department constructed an earthen dam across the lower end of a small valley in the hills about a mile back of the home, creating a reservoir with a capacity of about seventy-five acre-feet. The reservoir is called Fern Lake. A pipe line to the institution enables this water to be used for irrigation about the grounds, to supply fire hydrants, and also furnishes water for flushing purposes in some of the buildings. The quality of the water, however, renders it unfit for domestic use, and it is excluded from the domestic pipes.

A gas engine in the creek which traverses the estate pumps water through a pipe line to the dairy farm, where it is used for irrigating garden truck. Another pump in the creek bottom forces water to a small earthen reservoir on the hill above the buildings where it is admitted to the irrigation and fire mains on the Fern Lake system.

For a long time the domestic supply has not fully met the requirements of the institution in the summer months when the flow from the springs reaches its minimum and many attempts have been made to increase the flow by tunnels and cross-cuts, but without success. The department made careful investigation of the geologic formations and came to the conclusion that no material additional water supply could be developed from underground sources. This conclusion was verified two years ago when attempts were made to obtain water by deep wells bored at different points on the estate.

During the past summer engineers of the department have made reconnaisances of the mountains surrounding Sonoma Valley, and have found at least one site where it is believed a reservoir can be constructed which will store sufficient water to supply the Home with an abundance for all its purposes. The development of this supply will require the acquisition of the reservoir site and of rights of way, together with the construction of a pipe line several miles in length. Studies are being made to determine the flow of the stream for a basis of estimates of cost for the works necessary to utilize this apparent source.

When Fern Lake, above mentioned, was created, the dam which is earthfill with a clay and gravel puddle core, was designed so as to be enlarged. It was constructed to hold 15 feet in depth of water, and later was raised five feet. During the current biennium the dam was again raised five feet making the available depth 25 feet and the storage capacity about 114 acre-feet of water. The reservoir has a very small drainage tributary to it, and water to be stored must be brought from ravines north and south of it. It is not expected that these small streams will afford the lake's full capacity every year, but will do so most years.

The pump above mentioned as being used to pump water from Sonoma Creek into the Fern Lake Irrigation System was removed, and a 4-stage, 3-inch centrifugal pump driven by an electric motor was installed in its stead and which it is hoped will give much more effective service. Even with these adidtions to the water service, the supply is no more than sufficient to meet the present actual needs of the Home. It is imperative that other supplies be provided in the near future, and if plans now under consideration for the material enlargement of the institution be likely to materialize immediate steps should be taken to acquire a water supply to meet its demands.

A minor improvement effected in the last year was the repair of the leaky concrete distributing tank above mentioned. This does not add to the water supply but improves the means of distribution.

Preston School of Industry.

Water Supply. This institution located at Ione, Amador County, like nearly all other state institutions, finds its water supply inadequate to meet its constantly increasing needs.

The main supply is derived from an old water right, originally pertaining to mines, which was acquired when the school was first established. The water is diverted from Sutter Creek and conveyed in an old miners' ditch several miles to an artificial reservoir made by an earthen dam in a ravine. The water is heavily loaded with pulverized rock from the tailings of several quartz mills. The principal office of this reservoir is that of a settling basin in which a large part of the silt is deposited. Whatever storage capacity the reservoir originally had is largely reduced by the deposit named.

From the settling basin the water is conveyed in an open ditch to a small reservoir in the head of a ravine about a mile from the school and several hundred feet higher in elevation. The dam here is also of earth. The reservoir is small, its principal function being to regulate the flow of water which is conveyed in a riveted iron pipe to the school where it is distributed for use, part being used for irrigation of the grounds, and for fire protection, while a portion operates an electric power plant.

A few years ago the school management secured a small quantity of water from a ditch which supplies the town of Ione. This water is conveyed some six miles in a 4-inch screwed pipe and delivers the water into a tank in the tower of the administration building. When the pipe was laid, the funds were not sufficient to properly equip it with blow-off valves, and as the water carries considerable fine silt, the latter accumulated in the depressions, greatly reducing the capacity of the pipe.

During the past season the Department of Engineering was called upon to investigate the feasibility of increasing the school's water supply. It was found that the old ditch from the settling basin is in need of repairs. Several wooden flumes along the line are badly decayed and leaky, thus losing a considerable part of the water.

It is recommended that the ditch be repaired and the dam of the settling reservoir be raised six feet. Surveys have been made and plans and estimates will soon be submitted.

The domestic supply pipe has been fitted with blow-off valves, and the silt blown out, materially increasing the supply from that source. It is expected that when the suggested improvements are made in the ditch and reservoir the situation will be greatly relieved.

PLATE III.

p 22

Mount Whitney Fish Hatchery, Independence.

PLATE IV.

Patients' Cottage, Stockton State Hospital.

Tubercular Patients' Cottage, Agnew State Hospital.

State Fair Grounds.

Extension of Water System. The water pipes throughout the infield were rearranged and a system of sprinkling hydrants installed to irrigate the alfalfa with which the infield is planted.

Extension of Sewer System. Prior to the issuance of the last report the sewer system had been rearranged and connected with the city's sewers. Last summer some new connections were necessary to be made for the new exposition building, as well as the temporary structures erected for the State Fair, held in August of this year.

Whittier State School.

Water Supply. The water for this institution is obtained from the Whittier Water Company for domestic and fire uses, and from the Rincon Ditch Company for irrigation.

A controversy arose between the school and certain farmers along the ditch above where the state tapped it, as to the use of the water. The department succeeded in making an amicable arrangement between the parties which it is believed will obviate any further friction.

Marshall's Monument.

Water Supply. The erection of a new lodge for the custodian by the department necessitated improvement of the water supply. This was effected by laying about 3200 feet of 1½-inch pipe from some springs at a higher elevation than the house. A steel tank on a wooden tower 60 feet high was built, to which the water is conveyed and thence distributed to the lodge and throughout the grounds.

Sewers. A sewer was laid from the lodge, carrying the wastes to a point clear of the grounds.

San Quentin State Prison.

Water Supply. The water for domestic use at this institution is purchased from the water company. The quantity available from this source and the price paid for it, amounting to $1,500 a month, precludes its use for either fire protection or irrigation.

For fire purposes sea water is pumped into a tank on a hill above the buildings, while a small quantity for irrigating garden truck is obtained from wells.

A larger supply for both domestic and irrigation is greatly needed, and last year attempts were made to develop from wells, but without success.

Following this failure the department made investigations of the possibility of obtaining a supply adequate for the needs of the institution.

A reconnaissance discovered a reservoir site where a dam of moderate dimensions will store an abundance of water for all purposes of the prison. A pipe line about 7 miles in length would be required.

Sewerage at State Institutions. Several of the institutions have sewage disposal works of more or less elaborate design. The prevailing type is the hydrolitic tank with the effluent disposed of in irrigation, or discharged into nearby streams. This method is generally satisfactory and where complaints have arisen, it has been due to neglect in controlling the inflow so as to give it the correct time for hydrolitic action or in not cleaning out the sludge at proper intervals.

These conditions are brought about largely by reason of the inability of those in charge to understand the technic of the processes employed in reducing sewage wastes to an inoffensive state.

It is hoped that sometime a system of frequent inspections may be employed whereby the plants can be kept in efficient operation.

REPORT OF THE BUREAU OF ARCHITECTURE COVERING OPERATIONS FROM NOVEMBER 1, 1916, TO OCTOBER 1, 1918.

The Bureau of Architecture of the Department of Engineering has charge of all work of the Department of Engineering at forty-eight different state institutions and enterprises.

During the biennial period just ended, 114 different pieces of work have been completed; 50 additional pieces of work are now under construction and 16 more are being delayed on account of war conditions. Practically nothing has been done in connection with five of these 16, and these five, for which $1,050,000 is available, will be entirely omitted from the figures given in this report, which, therefore, will deal with a total of 175 different projects.

Of the 164 projects, construction of which is either completed or under way, 43 were contracted for and 121 are being constructed by day's labor. In the case of day's labor work, the bureau acts as contractor as well as architect, thus increasing office and inspection costs, but decreasing ultimate total cost of the project by eliminating contractor's profit. In connection with the remaining eleven of the total of 175 projects, office work has been completed, ready for actual construction to start.

Of the 175 projects, each one of ten covers innumerable small jobs which are classed under the head of "Repairs and Improvements" at ten of the larger institutions; 124 are projects of a value less than $10,000 each; 22 are projects of a value between $10,000 and $20,000 each; 15 are projects of a value between $20,000 and $50,000 each; and four are projects of a value in excess of $50,000 each.

These figures indicate that more than 75 per cent of the projects handled were of a value less than $10,000 each and most of these very much less than $10,000 each. This condition has made the architectural work involved much more expensive than it would have been otherwise.

The total expenditure for these 175 different pieces of work is $2,072,460. The office work in the bureau in connection with these 175 projects is costing $132,550, or 6½ per cent of their value. The cost of inspection is the expense involved in maintaining an inspector on the work during the entire time of construction and is the same as in private practice.

The 6½ per cent cost for office work mentioned above covers both contract and day's labor work. In private practice, 6 per cent is paid for architectural service in connection with contract work costing more than $10,000 and 10 per cent if the cost is below $10,000; 10 per cent additional is paid when the day's labor method is used; therefore, in connection with the 175 projects, under consideration in this report, the architectural service in private practice would have cost $217,000, or 10½ per cent of the total value of the work, instead of the $132,550 or 6½ per cent which it has cost in the bureau.

In addition to the work involved in the 175 projects above mentioned, a large amount of sketching has been done and consultation conducted covering projects not yet actually undertaken; this sketching and consulting will always be necessary as a basis for deciding upon future work. Our statutory men also spend a large amount of time giving required advice and counsel regarding technical matters to the various institution managements and state boards and departments.

In addition to the above, the bureau during the last two years has conducted two competitions for the selection of architects outside the bureau. The first was in connection with the San Francisco State Building which is to be constructed on the Civic Center in San Francisco, and the second for the Library and Courts Building and the Office Building which are to be constructed at Sacramento. Both of these competitions were entirely successful. Following the competition for the San Francisco State Building, the architects, Bliss and Faville of San Francisco, have completed the working drawings and specifications, and the bureau had done the mechanical and structural work covering working drawings and specifications, for the building, in accordance with the terms of the contract between the department and Bliss and Faville. The cost of this work by the bureau is included in the above total of $132,550, although this project is not included in the 175 herein reported upon. The taking of bids and construction of this building are being delayed until conditions return to normal, so as to make it possible to construct the building within the money available.

Messrs. Weeks and Day, architects of San Francisco, have been selected in connection with the Sacramento buildings, and work is being delayed until conditions become normal.

The reproductions of photographs which accompany this report have been selected as being typical of nearly all of the various kinds of buildings which the bureau is constructing for the state.

Following is a report as of date October 1, 1918, giving a summary showing progress made fourteen months after the appropriations became available:

REPORT INDICATING STATUS OF WORK HANDLED BY THE ARCHITECTURAL BUREAU OF THE STATE DEPARTMENT OF ENGINEERING SINCE THE LEGISLATURE OF 1917.

October 1, 1918.

Summary Showing Progress Fourteen Months After Appropriations Became Available.

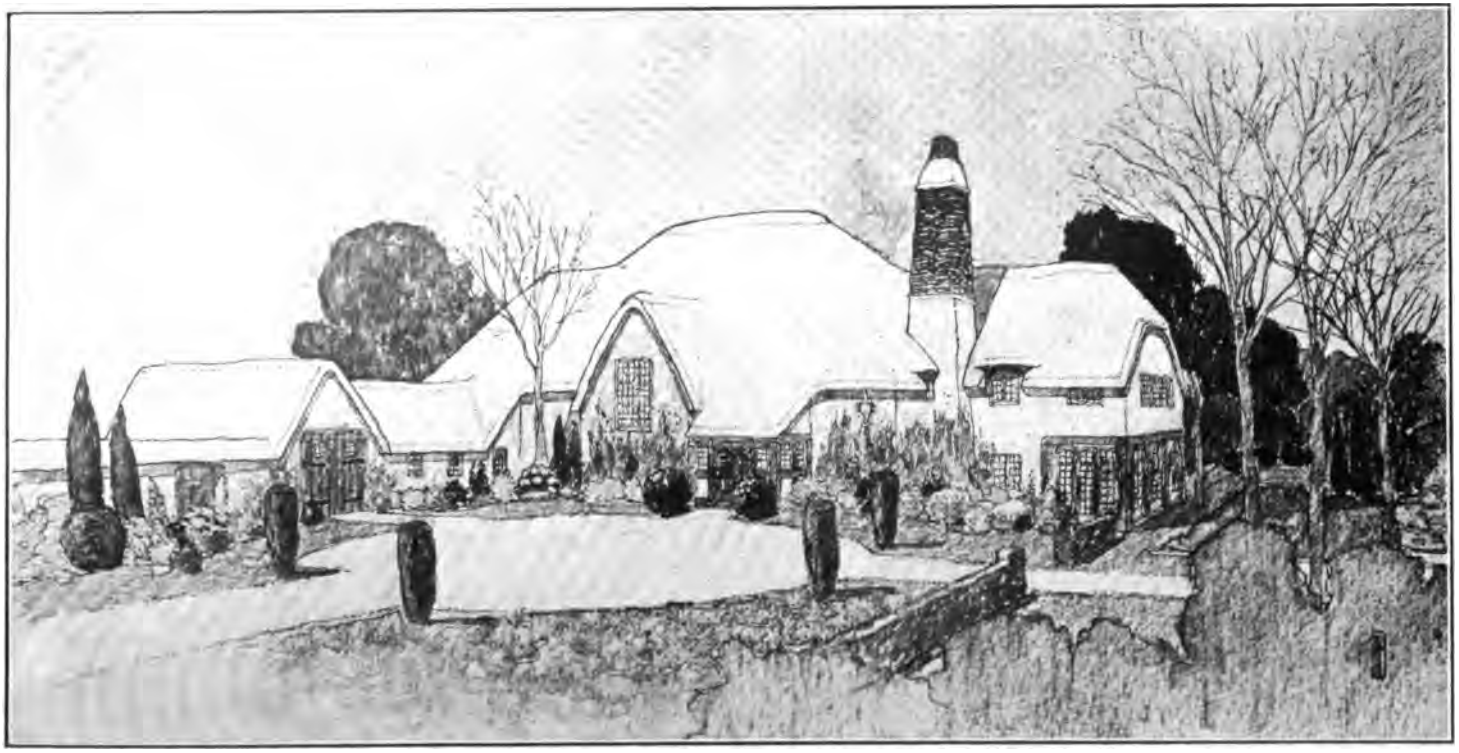
1. Number of items entirely or practically completed	94
2. Number of items on which office work is completed and construction under way	41
3. Number of items on which office work is completed but construction not yet started	5
4. Number of items on which preliminary work is completed and working drawings under way	1
5. Number of items on which preliminary work is completed and working drawings not yet started	3
6. Number of items on which preliminary work is under way	3
*7. Number of items on which nothing has been done	6
8. Number of items which have been abandoned	10

*Six of these are being delayed by circumstances over which this department has no control.

PLATE V.

Water tower; Service Building, Whittier State School.

PLATE VI.



Superintendent's Residence, Whittier State School.

REPORT INDICATING STATUS OF WORK HANDLED BY THE ARCHITECTURAL BUREAU OF THE STATE DEPARTMENT OF ENGINEERING SINCE THE LEGISLATURE OF 1917.

October 1, 1918.

Fund	Name	Appropriation	Cost of this work	Remarks
	Agnews State Hospital.			
Chap. 332, 1917	Workers' cottage for men	$45,000 00	$45,000 00	Office work complete. Under construction by contract; about 40 per cent complete.
Chap. 307, 1917	Cottage for female patients	28,000 00	28,000 00	Practically complete.
Cont. est.	Pumping plant for irrigation	1,800 00	1,800 00	Complete.
	Agricultural Park, Sacramento.			
Chap. 775, 1917	Agricultural pavilion	300,000 00	300,000 00	Office work complete. Under construction by subcontracts; about 60 per cent complete.
Chap. 281, 1917	Miscellaneous repairs to sheds, barns, etc., for 1917 and 1918 fair	8,500 00	8,500 00	Completed.
Chap. 280, 1917	Miscellaneous repairs to sheds, barns, etc., for 1917 and 1918 fair	5,000 00	5,000 00	Completed.
Chap. 358, 1917	Repairs to roof, manufacturers' pavilion		1,000 00	Completed.
	California School for the Deaf and the Blind, Berkeley.			
Chap. 348, 1917	Repairing greenhouse	20,000 00	500 00	Completed.
Chap. 348, 1917	New foundations, etc., for horse barn	20,000 00	800 00	Completed.
Chap. 348, 1917	Moving horse barn	20,000 00	1,000 00	Completed.
Chap. 348, 1917	Heating in greenhouse	20,000 00	800 00	Completed.
Chap. 348, 1917	Alterations to second floor of laundry	20,000 00	1,200 00	Completed.
Chap. 348, 1917	Laundry repairs	20,000 00	300 00	Completed.
Chap. 348, 1917	Grading for cow corral	20,000 00	5,000 00	Completed.
Chap. 348, 1917	Garage for superintendent's residence	20,000 00	300 00	Completed.
Chap. 348, 1917	Miscellaneous repairs and improvements	20,000 00	10,100 00	Completed.
Chap. 293, 1917	Completion of heating plant	21,000 00	21,000 00	Completed.
Chap. 294, 1917	Completion of electric wiring	5,000 00	5,000 00	Completed.
	California Polytechnic School, San Luis Obispo.			
Chap. 471, 1917	Repairing the buildings	5,000 00	5,000 00	Completed.
Chap. 316, 1917	Barn	4,000 00	4,000 00	Abandoned during war.

REPORT INDICATING STATUS OF WORK HANDLED BY THE ARCHITECTURAL BUREAU OF THE STATE DEPARTMENT OF ENGINEERING SINCE THE LEGISLATURE OF 1917—Continued.

October 1, 1918.

Fund	Name	Appropriation	Cost of this work	Remarks
	California School for Girls, Ventura.			
Chap. 367, 1917	Two cottages	$63,000 00	$53,000 00	Office work complete. Contract just being executed. Construction will start at once.
Chap. 362, 1917	Trades building and gymnasium	30,000 00	30,000 00	Office work complete. Contract just being executed. Construction will start at once.
Chap. 364, 1917	Service connections to new buildings	6,000 00	6,000 00	Preliminary data now being secured.
Chap. 474, 1917	Water system	10,000 00	10,000 00	Preliminary data now being secured.
Chap. 366, 1917	Improvements of grounds	4,000 00	4,000 00	Being attended to by institution as needed.
Chap. 361, 1917	Ice plant in commissary	2,000 00	2,000 00	Completed.
Chap. 365, 1917	Heating of office in commissary building and manor house	1,200 00	1,200 00	Completed.
	Chico State Normal School.			
Chap. 262, 1917	Addition to training school building	16,000 00	15,500 00	Completed.
	Exposition Park, Los Angeles.			
City	Horse barns for Liberty Fair		6,000 00	Practically completed.
Expo. Park	Increasing heating plant, Exposition Building	2,800 00	2,800 00	Completed.
Expo. Park	Interior alterations, Exposition Building	17,000 00	17,000 00	Completed.
Expo. Park	Elevator repairs	300 00	300 00	Completed.
	Folsom State Prison.			
Chap. 278, 1917	Repairs and improvements	25,000 00	25,000 00	Being done at institution as needed.
Chap. 276, 1917	Prison school building	10,000 00	10,000 00	Office work complete. Being built by institution labor. About 20 per cent complete.
Chap. 254, 1917	Sewage disposal system	11,000 00	11,000 00	Completed.
Chap. 573, 1909	Cottage for employees	1,300 00	1,300 00	Completed.
Chap. 279, 1917	Construction of new cottages for employees	12,500 00	10,000 00	Practically completed.
Chap. 279, 1917	Repairs to existing cottages for employees	12,500 00	2,500 00	Completed.
Chap. 485, 1917	Purchase of boilers and additional installation to power plant	15,000 00	13,500 00	Office work complete. Boiler and other equipment on hand. Installation will begin when building is ready.
Chap. 485, 1917	Power house building	15,000 00	1,500 00	Office work complete. Under construction by institution labor. About 25 per cent complete.
	Fresno State Normal School.			
Chap. 240, 1917	Swimming pool and balconies in gymnasium	17,000 00	8,000 00	Completed.
Chap. 240, 1917	Electrical equipment	17,000 00	3,000 00	Office work complete. Materials now under order.
Chap. 240, 1917	Alterations to cafeteria and caretakers' cottage	17,000 00	3,500 00	Completed.

	Humboldt State Normal School.			
Chap. 287, 1917	Painting temporary buildings	1,000 00	1,000 00	Completed.
Chap. 743, 1917	Grading of site	230,000 00	8,500 00	Completed.
Chap. 743, 1917	Main buildings	230,000 00	230,000 00	Abandoned during war. Office work completed.
Chap. 743, 1917	Main sewer	230,000 00	2,000 00	Completed.
Chap. 743, 1917	Moving temporary buildings	230,000 00	1,000 00	Completed.
	Industrial Home for the Adult Blind.			
Chap. 292, 1917	Alterations and additions to buildings	8,700 00	7,000 00	Completed.
Chap. 292, 1917	Miscellaneous repairs	8,700 00	1,700 00	Completed.
Chap. 288, 1917	Improvements for grounds	960 00	960 00	Completed.
Chap. 289, 1917	Digging shaft and tunnels for water supply	4,250 00	2,000 00	Completed.
Chap. 289, 1917	Pumping equipment	4,250 00	500 00	Completed.
	Los Angeles State Normal School.			
Chap. 335, 1917	New garage and additions to Manual Arts Building and Library Cloister	14,800 00	10,000 00	Completed.
Chap. 334, 1917	Repairs to artificial stone	3,000 00	800 00	Completed.
Chap. 334, 1917	Treatment of art stone	3,000 00	1,500 00	Practically complete.
Chap. 334, 1917	Changes in heating system	3,000 00	600 00	Completed.
Chap. 335, 1917	Fire escapes to balcony of auditorium	14,800 00	1,400 00	Office work complete. Contract just let.
Emergency	Barracks for student soldiers	15,000 00	14,000 00	This job initiated September 6, 1918. Practically complete.
	Mendocino State Hospital.			
Chap. 296, 1917	New laundry and bakery	28,000 00	15,000 00	Completed.
Chap. 296, 1917	Oven for bakery	28,000 00	3,000 00	Completed.
Chap. 827, 1917	New patients' cottage	28,000 00	20,000 00	Office work complete. Under construction by day labor. About 90 per cent complete.
Chap. 370, 1917	New boilers	18,000 00	18,000 00	Part of equipment on hand and being installed by day labor. About 20 per cent complete.
Chap. 267, 1917	Water softening plant	7,500 00	7,500 00	Office work complete. Work of installation being done by day labor. About 65 per cent complete.
Chap. 268, 1917	Reconstruction of ward 7	5,000 00	5,000 00	Office work complete. Under construction by day labor. About 50 per cent complete.
Chap. 325, 1917	Repairs to plumbing	5,000 00	5,000 00	Being done at institution as needed.
Chap. 871, 1917	Repairing structural defects in administration building	3,500 00	3,500 00	Completed.
Chap. 326, 1917	Enlarging operating room	3,000 00	3,000 00	Abandoned.
Chap. 269, 1917	Repairs to flooring	2,500 00	2,500 00	Completed.
Cont. est. 1058	Rewiring	11,500 00	11,500 00	Completed.
Cont. est. 1058	Ground lighting	2,500 00	2,500 00	Office work complete. Abandoned because of war conditions.
Cont. est.	Auxiliary water supply	6,900 00	6,900 00	Completed.

REPORT INDICATING STATUS OF WORK HANDLED BY THE ARCHITECTURAL BUREAU OF THE STATE DEPARTMENT OF ENGINEERING SINCE THE LEGISLATURE OF 1917—Continued.

October 1, 1918.

Fund	Name	Appropriation	Cost of this work	Remarks
	Napa State Hospital.			
Chap. 242, 1917	Pathological laboratory	$20,000 00	$20,000 00	Abandoned during war. Office work completed.
Chap. 480, 1917	Two cottages	58,000 00	52,000 00	Office work complete. Under construction by contract. About 10 per cent complete.
Chap. 241, 1917	Cottage for convalescent females	15,000 00	15,000 00	
Cont. est.	Repairs to gas plant	1,200 00	1,200 00	Completed.
Chap. 398, 1917	Electric elevators	10,000 00	10,000 00	Completed.
Chap. 399, 1917	Sewer line	10,000 00	10,000 00	Completed.
Chap. 397, 1917	Repairs to boiler house equipment	6,000 00	4,500 00	Completed.
Chap. 397, 1917	Repairs to boiler house	6,000 00	1,500 00	Preliminary data obtained.
	Norwalk State Hospital.			
Chap. 346, 1917	Workers' cottage for females and two receiving cottages	135,000 00	130,000 00	Office work complete. Under construction by contract; about 75 per cent complete.
Chap. 346, 1917	Service connections for cottages	135,000 00	5,000 00	Office work complete. Under construction by day labor; about 80 per cent complete.
Chap. 345, 1917	Administration building	50,000 00	46,000 00	Abandoned during war.
Chap. 344, 1917	Farm buildings	36,700 00	36,700 00	Question of construction during war not yet determined by Board of Control.
Chap. 343, 1917	Superintendent's cottage	10,000 00	9,000 00	Office work complete. Under construction by day labor; about 50 per cent complete.
Cont. est.	Pumping plant for irrigation service	5,300 00	5,300 00	Completed.
Chap. 345, 1917	Service connections for administration building	5,000 00	4,000 00	Completed.
	Preston School of Industry.			
Chap. 301, 1915	Power plant and water system	30,000 00	12,000 00	Completed.
Chap. 172, 1913	Cottages 4 and 5	23,000 00	12,000 00	Cottage No. 4 complete; cottage No. 5, 50 per cent complete.
Chap. 411, 1917	Repairs and improvements to buildings	10,000 00	10,000 00	Being attended to at institution as needed.
Chap. 529, 1913	Conversion of band cottage into hospital	12,000 00	6,000 00	This project initiated in July, 1918. Office work complete and materials now being ordered.
	San Diego State Normal School.			
Chap. 246, 1917	Paving around buildings	5,500 00	2,000 00	Completed.
Chap. 382, 1917	Miscellaneous repairs to buildings	7,000 00	8,000 00	Completed.
Chap. 383, 1917	Miscellaneous electric work	7,000 00	1,800 00	Completed.
Chap. 383, 1917	Time-clock system	7,000 00	2,200 00	Completed.
Chap. 246, 1917	Miscellaneous painting around grounds	5,500 00	500 00	Completed.
Chap. 308, 1917	Paving in front of school	1,500 00	1,500 00	Completed.

PLATE VII.

Administration Building, Norwalk State Hospital.

PLATE VIII.

Humboldt State Normal School, Arcata.

	San Francisco State Normal School.			
Inst. cont.	Repairs to buildings on account of fire	2,000 00	2,000 00	Completed.
Chap. 491, 1917	Purchase of site, construction of new buildings and improvement of grounds	775,000 00	775,000 00	Nothing being done; institution not ready.
	San Francisco State Office Building.			
Chap. 541, 1913	Office building for state offices	1,000,000 00	1,000,000 00	Office work complete. Abandoned during war.
	San Jose State Normal School.			
Chap. 258, 1917	Assembly hall	80,000 00	70,000 00	Office work complete. Abandoned during war.
	San Quentin State Prison.			
Chap. 238, 1917	Electrification and rewiring	32,500 00	32,500 00	Practically complete insofar as present funds will go.
Chap. 284, 1917	Administration building	20,000 00	10,000 00	Office work complete. Under construction by day labor. About 25 per cent complete.
Chap. 284, 1917	Recreation building	20,000 00	8,000 00	Office work complete. Under construction by day labor. About 30 per cent complete.
Chap. 253, 1917	Electrification and rewiring	3,500 00	3,500 00	Completed.
Chap. 285, 1917	New additions to farm building	5,000 00	5,000 00	Waiting for institution to furnish preliminary data.
	Santa Barbara State Normal School.			
Chap. 257, 1917	Gymnasium building	20,000 00	18,000 00	Completed.
Chap. 250, 1917	Sewer system	1,000 00	1,000 00	Completed.
	Sonoma State Home.			
Chap. 266, 1917	Laundry building	22,500 00	20,000 00	Office work complete. Under construction by contract. About 20 per cent complete.
Chap. 265, 1917	Bakery building	15,000 00	11,000 00	Office work complete. Under construction by contract. About 20 per cent complete.
Chap. 264, 1917	Cottage for low grade girls	15,000 00	15,000 00	Practically complete.
Chap. 351, 1917	Steam pipe extension	8,100 00	8,100 00	Completed.
Chap. 265, 1917	Ovens for bakery	15,000 00	2,600 00	Office work complete. Bids taken and contract awarded. Construction waiting on bakery building.
Chap. 353, 1917	Reconstruction and enlarging of Madrona Hall for commissary	5,000 00	5,000 00	No start can be made until laundry and bakery are completed and occupied.
Chap. 262, 1917	Reflooring	4,000 00	4,000 00	Completed.

REPORT INDICATING STATUS OF WORK HANDLED BY THE ARCHITECTURAL BUREAU OF THE STATE DEPARTMENT OF ENGINEERING SINCE THE LEGISLATURE OF 1917—Continued.

October 1, 1918.

Fund	Name	Appropriation	Cost of this work	Remarks
	Southern California State Hospital.			
Chap. 338, 1917	Cottage No. 17	$45,000 00	$41,000 00	Completed.
Chap. 404, 1917	Nurses' home	15,000 00	12,500 00	Practically completed.
Chap. 404, 1917	Industrial building	15,000 00	2,500 00	Completed.
Chap. 336, 1917	New boiler	8,000 00	8,000 00	Boiler delivered and set up. Department's work complete. Bricking up of boiler being done by institution.
Chap. 337, 1917	New wiring in old buildings and grounds	8,000 00	8,000 00	Under construction by day labor; about 85 per cent complete.
Chap. 339, 1917	Pump, motor connections, etc., to new well	3,000 00	3,000 00	Completed.
Chap. 338, 1917	Service connections to cottage 17	45,000 00	1,250 00	Completed.
Chap. 404, 1917	Service connections to nurses' home	15,000 00	1,000 00	Completed.
Cont. est.	Repairs to main buildings on account of earthquake damage	3,000 00	6,000 00	Practically completed.
	Stockton State Hospital.			
Chap. 330, 1917	Cottage for disturbed patients	45,000 00	45,000 00	Bids opened on September 30th—being considered.
Chap. 272, 1917	Tubercular hospital	10,000 00	10,000 00	Bids opened on September 30th—being considered.
Chap. 235, 1917	Alterations and additions to bakery and kitchens	15,000 00	8,000 00	Completed.
Chap. 235, 1917	Refrigerating plant for kitchen	15,000 00	1,000 00	Completed.
Chap. 234, 1917	Repairs and additions to mechanical equipment	8,000 00	8,000 00	Completed.
Cont. est.		6,515 00	6,515 00	Completed.
Chap. 792, 1917	Crematory	5,000 00	4,500 00	Building is completed and retort is now being built. About 15 per cent complete.
	Veterans' Home.			
Chap. 263, 1917	Repairs and improvements to buildings	15,000 00	15,000 00	Being attended to at institution as needed.
Chap. 488, 1917	Boilers	15,000 00	15,000 00	Nothing being done. No urgent need.
Chap. 243, 1917	Tubercular ward	10,000 00	10,000 00	Office work complete. Under construction by day labor. About 85 per cent complete.
Chap. 394, 1917	Quarters for inebriates	8,000 00	8,000 00	Office work complete. Under construction by day labor. About 20 per cent complete.
Chap. 395, 1917	Chapel	5,000 00	5,000 00	
Chap. 426, 1917	Enlargement of hospital kitchen	4,000 00	3,500 00	Practically complete.
Chap. 392, 1917	Plumbing and repairs to plumbing	2,500 00	2,500 00	Being attended to at institution as needed.
Chap. 244, 1917	Painting buildings	7,500 00	7,500 00	Nothing being done as yet.
Chap. 391, 1917	Completing electric wiring	2,500 00	2,500 00	Completed.
Chap. 213, 1915	Repairs to plastering hospital	15,000 00	3,500 00	Completed.
Chap. 263, 1917	Quarters for assistant physician	15,000 00	1,000 00	Completed.

	Whittier State School.		
Chap. 357, 1917	Steam distribution system	45,000 00	10,000 00	Office work complete. Installation being made by day labor. About 30 per cent complete.
Chap. 238, 1915	Cottage No. 12	60,000 00	15,000 00	Completed.
Chap. 356, 1917	Cottage No. 11	82,500 00	40,000 00	Office work complete. Under construction by day labor. About 90 per cent complete.
Chap. 356, 1917	New shop buildings and power house	82,500 00		Office work complete. Construction just started.
Chap. 355, 1917		25,000 00	35,000 00	
Chap. 356, 1917	Laundry and tailor shop	82,500 00	15,000 00	Office work complete. Construction will not start until power house and shop buildings are complete.
Chap. 357, 1917		45,000 00		
Chap. 355, 1917	Power house equipment	25,000 00	8,000 00	Office work complete. Construction will not start until power house and shop buildings are complete.
Chap. 356, 1917	Chicken and rabbit houses	82,500 00	3,000 00	Completed.
Chap. 356, 1917	Quarters for employees	82,500 00	3,500 00	Abandoned.
Chap. 356, 1917	Water tower	25,000 00	3,500 00	Working drawings now being made.
	New Institutions and Miscellaneous.		
Chap. 768, 1917	State Printing Office	100,000 00	100,000 00	Nothing being done. No site selected.
Chap. 776, 1917	Pacific Colony (home for feeble minded)	250,000 00	250,000 00	Considerable preliminary office work has been done. Real progress delayed pending selection of site.
----------	State Capitol Extension buildings	3,000,000 00	3,000,000 00	Competition completed and architect selected. Further progress stopped because of war.
Chap. 321, 1917	Restoring old custom house, city of Monterey	5,500 00	5,500 00	Completed.
Chap. 322, 1917	Restoring old theater, city of Monterey	3,500 00	3,500 00	Completed.
Chap. 368, 1917	Painting exterior of Capitol	5,000 00	2,500 00	Completed.
Chap. 248, 1917	Repairs and improvements, Women's Relief Corps Home Ass'n	5,000 00	5,000 00	Completed.
Chap. 430, 1917	Equipment of vault, office of Secretary of State	4,000 00	4,000 00	Completed.
Chap. 400, 1917	Improvement of grounds at Marshall's Monument, El Dorado Co.	4,000 00	4,000 00	Completed.
Chap. 311, 1917	Restoration of Fort Ross, Sonoma	1,500 00	1,500 00	Part of work completed. Balance of work under way.
Chap. 376, 1917	Electric lighting at Sutter's Fort, Sacramento	1,000 00	1,000 00	Completed.
Chap. 759, 1917	Office building for State Mining Bureau at Coalinga	4,000 00	4,000 00	Completed.
Chap. 759, 1917	Office building for State Mining Bureau at Taft	4,250 00	4,250 00	Completed.
Bd. of Control Emergency	Miscellaneous repairs to Governor's mansion on account of explosion	----------	1,500 00	Completed.
Bd. of Control Emergency	New heating system, Governor's mansion	----------	1,000 00	Completed.
Fish and Game Preservation	Fish hatchery, Yosemite Valley	----------	----------	Office work complete. Abandoned during war.

PART II.

HYDROECONOMICS.

Every body of water has its uses, and often one body may have several uses, all contributing to the welfare of man. Broad arms of the sea, stretching inland, offer easy highways for cheap communication and transportation for the communities along their shores. Broad rivers afford like facilities for commerce, and also furnish water for irrigation of the lands along their banks to produce that commerce. Tributary streams contribute power for lighting the streets and homes of communities created by the benign influences of the others, as well as operating the myriad wheels of industry. And all unite, in the mad moods of nature, to send destruction and ruin upon the works of their beneficence.

Each body or stream has problems of its own to be solved that its forces may be directed to beneficial use, some akin and some dissimilar in the methods of their solution.

SACRAMENTO RIVER PROBLEMS.

That in the Sacramento Valley lie a million acres of land periodically laid waste by the flood waters of the Sacramento River is too well known to need extended mention here. That concrete effort is being made to rescue that vast body of land from waste and convert it into an asset to the state is also known and the methods by which reclamation is to be effected have been so fully set forth in previous reports of this department that no details of the plans need to be extended at this time.

Suffice it to say that the plans for the ultimate protection of the lands subject to overflow in the Sacramento Valley and the adjacent deltas of Mokelumne and San Joaquin rivers were formulated by government engineers acting under the directions of the Caminetti Act, passed in 1893.

After forty-four years of agitation and of abortive effort at individual unit reclamation, the United States Debris Commission was created to regulate hydraulic mining so that no further mining debris should reach the navigable rivers, and to formulate plans for the improvement of the streams.

At the end of seventeen years devoted to surveys, research and studies, the commission reported a plan for the improvement of navigation, control of floods and reclamation of lands.

The report, which was presented in 1911, and published as House Document No. 81, Sixty-second Congress, first session, recommended

that the cost of the work be borne jointly by the United States, the state of California and the landowners who would be direct beneficiaries of complete reclamation and protection.

By an act of the California legislature, approved December 24, 1911,[1] the report of the Debris Commission was approved with such modifications and amendments as might be found advisable, and there was created a body known as the State Reclamation Board, to administer the matter in behalf of the state. The plan submitted is, in brief, as follows:

(*a*) To construct strong levees on each bank of the river so as to make the channel carry as much water as possible with safety.

(*b*) To construct weirs at selected points through which to discharge excess waters under control.

(*c*) To construct artificial channels through the basins of ample size to convey the excess waters turned into them through the weirs. These by-passes to return their waters to the main river about 15 miles above the mouth of the latter at Suisun Bay.

(*d*) To enlarge the lower 15 miles of the river channel so it will safely carry the united waters of the river and the by-passes.

The total cost of the project as proposed was estimated at $33,800,000.

A preliminary report had been submitted in 1907, showing the need of enlarging the mouth of the Sacramento River as a first step in any comprehensive scheme and estimating the initial cost to be $800,000, recommending an equal division of expense between the United States and the state. The legislature promptly accepted the recommendation and appropriated funds to cover the state's share.

The law creating the Reclamation Board provided that no levees should be constructed by private parties unless they conformed to the plan and were approved by the board.

The adoption of a settled policy for flood control and reclamation stimulated individual effort to such a degree that much of the public work proposed by the plan was effected by private enterprise, and a recasting of estimates by the Debris Commission, submitted early in 1913, showed a reduction in the probable cost to the governments from $22,000,000 to $11,200,000,[2] as the joint cost to the public.

This last estimate did not include the $800,000 already provided by the Congress and legislature for channel enlargement. The commission recommended that one-half of the estimated cost be paid by the United States and the other half by the state. This proposition was formally approved by the adoption by Congress of the Flood Control Act of March 1, 1917, and by the state legislature, as above set forth.

[1] Chapter 25, Statutes, extra session, 1911.
[2] River and Harbor Com. Doc. No. 5, 63d Cong. 1st Sess.

Two large suction dredges, the *Sacramento* and *San Joaquin*, were built and began the task of enlarging the mouth of the Sacramento in the summer of 1913. That work has steadily progressed ever since excepting for a short time during the last year, when the dredges were temporarily withdrawn and employed in dredging to expedite war work at Oakland and Mare Island, upon completion of which they were returned to the river work.

The original estimate of earth to be moved in enlarging the channel below Cache Slough, as published in the report[3] was 148½ million cubic yards, of which four million and eighty-three thousand cubic yards would be used in levees. It has been quite a problem to find dumping ground for this vast volume of material, which, if spread evenly over the ground, would cover 3000 acres about 30 feet deep. Much of the land which is required for the purpose is extremely fertile peat soil, and to cover it 30 feet deep, or any depth, for that matter, with dredgings, means destruction of its productiveness for several years. Fortunately, though, a very large portion of the spoil can be disposed of by filling the old channels, like the one around Horseshoe Bend, and others outside the lines of improvement and which will be abandoned as water-carriers when the enlarged cut is completed. Also along the west side of the river a system of hills rises which has many undulations, extending back from the water's edge, which can be utilized for filling up to the 35-foot contour.

The state has acquired title to, or easements upon, nearly all of the lands to be required for the purposes of this part of the project.

In acquiring easements for the deposit of dredged material on lands in Sherman Island, the state agreed to protect adjoining lands from injury. A drainage ditch serving a large body contiguous to a spoil field became partly filled from mud escaping into it, and the Department of Engineering had it cleaned, at a cost of $2410.

The state has also expended $12,400 in constructing a levee to hold back spoil deposits.

The prosecution of work on the "upper project," that is, the construction of levees forming by-passes by private interests, and of structures accessory thereto, has been going on, though on a much reduced scale, owing to restrictions imposed by war conditions.

One of the most notable achievements in this field has been the completion of the Bryte Weir, which is intended to divert surplus waters from Sacramento River into the Yolo By-pass about four miles above the city of Sacramento.

In view of the fact that the river below the confluence of Feather River is calculated to carry 50,000 second-feet of water, to which the

[3] H. Doc. 81, 62d Cong. 1st Sess.

American River entering above the city may contribute 125,000 second-feet, and that the capacity of the improved channel at and below the city is only a little more than 100,000 second-feet, the completion of the weir and its successful operation was a consummation imperatively necessary for the welfare of the Capital City, should floods recur such as have been experienced within the recent past.

Anticipating that a full report will be published by the Reclamation Board, under whose direction the work is being conducted, further discussion of the subject is left to that document.

HYDROGRAPHIC WORK.

All matters of drainage, improving and rectifying river channels and other work on any river or slough connecting with San Francisco Bay, San Pablo Bay, and Suisun Bay, and the tide waters flowing in said bays, or streams elsewhere in the state, wherein state moneys are expended, are placed under the management of the Department of Engineering. The duties so prescribed by law include improving the navigability of such waters, acquiring rights of way for improvements; purchase, construction and operation of dredges and other equipment required for such work; making surveys, investigations and reports upon the feasibility of canalizing the rivers and constructing navigable canals; surveys, investigations and plans for flood control upon any stream, the flood waters of which may injure or menace lands in California, including the examination and supervision of dams, and investigation of rainfall, snowfall and run-off affecting or tending to affect navigation or flood control upon any of the streams of the state.

Owing to the loss of personnel, the scarcity and abnormally high price of material and other limitations due to war conditions, the activities of the department in these matters for the last two years has been confined to a rigidly enforced minimum.

River Work.

Owing to the fact that the climate of the Great Valley is passing through a "dry" cycle, no great floods have occurred in either stream system for several years. Not since 1911 has the San Joaquin experienced a flood, and 1909 was the last high water in the Sacramento which reached dangerous conditions.

As a consequence of several years immunity from floods, there have been no crevasses formed requiring closures or extensive protection works.

Long-continued low plane of the water surface, however, is conducive to active caving of the alluvial banks, and in places this has occurred to the great loss of good land and destruction of levees, creating conditions where serious breaches would likely occur at the next flood. The

department has kept close watch of such conditions, and wherever danger threatened has applied remedial measures.

The principal work of the river improvement division since the last report has been to repair and maintain revetment previously laid and to place new revetment where conditions demanded.

Wherever the placing of protective works will inure to the direct benefit of adjacent lands because of increased security against flood damage, the owners are required to contribute a portion of the cost, in proportion to the benefits so received.

The work executed by the river division during the two years past has consisted principally of completing work that was in progress at the time of the last report; of repairing and extending work previously executed. Only one extensive and one or two minor jobs of new work were undertaken. The work is summarized as follows:

San Joaquin River.		
Lorenzen Bend, repairs and extensions		$2,287 78
Paradise Bend, repairs and extensions		1,431 40
New Banta Reclamation District, repairs and extensions		1,979 24
Reclamation District No. 17, repairs and extensions	$1,080 17	
Reclamation District No. 17, new mattress	2,286 97	
		3,367 14
Reclamation District No. 544, repairs and extensions		1,525 76
Sacramento River.		
Three-mile Slough, pile bulkhead, repairs		786 03
Edinger Farm, near Hood, new pile bulkheads		3,959 06
(State, Sacramento County and Mr. Edinger, each one-third.)		
Meridian, brush mat, repairs and extension		307 81
Mad River.		
Brush bulkheads, repairs and extensions		1,937 29

NOTE.—In all of above work, excepting at Edinger Farm, adjoining property owners contributed one-half of the cost.

Mokelumne River.

Terminus Landing. The levees protecting Reclamation District No. 548 along South Fork of Mokelumne River and Potato Slough are exposed to severe action from a long fetch up the river as well as across submerged Bouldin Island. They were becoming badly disintegrated and in danger of destruction from floods of the river.

A breach would cause flood waters to carry sand into the channels of Potato and Connection sloughs to the injury of navigation thereon, both of which streams are important highways for the transportation of produce from adjacent territory to market.

A new type of revetment was introduced here, consisting of sheet concrete covering the slope of the embankment and rising in a parapet at the top, and protected at the bottom by a vertical toe wall, 12 inches deep. The parapet rises vertically 19 inches with a curved face toward the water. It serves admirably to turn back the waves running up the slope and prevents any water being driven over the levee.

The length of this work was 3,310 feet, width on 2 to 1 slope, including toe wall and parapet is 18 feet 10 inches and thickness 3 inches. Triangle wire mesh reinforcement was used throughout. Expansion joints were placed every 20 feet. The cost of the work, including grading the slope, was $4.1357 per lineal foot, or $0.2196 per square foot in place, or a total cost of $13,689.41, which was borne equally by the state and district.

Flow measurements.

Since this department is charged with the duty of caring for navigation interests on the streams and also is required to foster irrigation enterprises, it is conceived to be quite necessary to secure data which will show how far the navigability of the river may be affected by withdrawals of water for irrigation purposes.

The rapid extension of rice culture in the Sacramento Valley is resulting in the diversion of water from the river in a constantly increasing volume.

Investigations to ascertain the quantity abstracted and its effect upon the river flow were commenced in the summer of 1917, and resumed in the season just past. All diversions are made by pumping directly from the river, the water being discharged into and carried to the lands by pipes or open ditches. A catalog of all pumping plants was made, containing considerable detailed information as to size, capacity, type of pump, and how operated. A table giving this information is inserted herewith.

It was endeavored to make the list complete and it is believed that no important diversion has been omitted, but it was not possible to make graphic records of the quantity of water taken, and that information is largely obtained from statements made by those in charge.

Owing to the difficulty of holding experienced hydrographers, several changes in the party having occurred by reason of the men being called to the colors, the work was greatly restricted in scope from that which had been desired.

One result of the curtailment was that no investigations were made below Knights Landing this year.

Analysis of the data set forth in the annexed table will not be presented at this time.

A conflict believed by the department to be impending between interests using the waters of the Sacramento Valley is discussed under the title Conflict of Interests, page 70.

Pumping Plants on Sacramento River Between Tehama and Knights Landing.

(a) Location		Owner	(b) Power		(c) Pumps			Capacity G. P. M.	(d) Acre-ft. Diversion
Mi.	Place		Type	H. P.	No.	Size	Type		
176	R	Town of Tehama	Electric		1	4"	Horizontal centrifugal		11
154		Sacramento Valley Irrigation Company	Electric	350	3	84"	Screw.		
154		Sacramento Valley Irrigation Company	Electric	250	1	84"	Screw.		
154		Sacramento Valley Irrigation Company	Electric	225	1	48"	Horizontal centrifugal	360,000	170,666
154		Sacramento Valley Irrigation Company	Electric	350	1	50"	Horizontal centrifugal.		
154		Sacramento Valley Irrigation Company	Electric	350	1	50"	Horizontal centrifugal.		
152		Holecek Brothers	Electric	15	1	6"	C. C. L.	1,500	45
151½		Sacramento Valley Sugar Company	Electric	150	2	18"	Vertical centrifugal	ea. 9,000	
151½		Sacramento Valley Sugar Company	Electric	50	1	12"	Vertical centrifugal	4,500	5,730
151½		J. Nola	Gas	15	1	6"	Vertical centrifugal	1,050	24
147½	L	Walker & Crassey Rovney Hop Ranch	Electric	15	1	6"	Horizontal centrifugal	900	120
147½	L	Walker & Crassey Rovney Hop Ranch	Electric	25	1	5"	Horizontal centrifugal	700	80
135½		Phelan Estate			1	6"	Horizontal centrifugal	900	18
133	L	Frank Rico	Gas	25	1	10"	Horizontal centrifugal	900	20
128	R	W. H. Stewart	Tractor	20	1	6"	Horizontal centrifugal	1,800	52
126	R	O. L. Leonard	Electric	30	1	10"	Horizontal centrifugal	3,000	2,190
124.3	R	D. A. Shellove	Electric	75	1	15"	Horizontal centrifugal	10,000	4,000
124.2	R	Provident Irrigation District	Electric	2,000	4	42"	Horizontal centrifugal	72,000	100,000
123.8	R	Gallwick	Electric	15	1	6"	Horizontal centrifugal	900	Idle
116.9	L	M. J. Jones	Gas	15	1	6"	Horizontal centrifugal	900	Idle
116.5	L	M. J. Jones	Electric		1	12"	Horizontal centrifugal	1,400	30
116	L	Butte City	Electric	5	1	5"	Plunger	35	56
115.5	L	E. L. Steele	Electric	50	1	12"	Horizontal centrifugal	450	120
112.7	R	Princeton-Colusa-Glenn Irrigation District	Electric	200	1	30"	Horizontal centrifugal	35,000	20,539
111.8	L	Moulton Irrigated Land Company	Electric	400	1	50"	Horizontal centrifugal	75,080	
111.8	L	Moulton Irrigated Land Company	Electric	150	1	30"	Horizontal centrifugal	35,000	
111.8	L	Moulton Irrigated Land Company	Electric	100	1	24"	Horizontal centrifugal	22,000	58,789
109.2	R	W. A. Xerxa	Electric	50	1	16"	Horizontal centrifugal	8,000	450
105	L	Moulton Irrigated Land Company	Electric	150	1	24"	Horizontal centrifugal	12,000	1,434
104	L	Rice Land and Products Company	Electric	300	2	24"	Horizontal centrifugal	30,000	
104	L	Rice Land and Products Company	Electric	250	1	36"	Horizontal centrifugal	50,000	11,555
103	R	Colusa Irrigation District	Electric	150	2	18"	Horizontal centrifugal	20,000	
103	R	Colusa Irrigation District	Electric	400	2	30"	Horizontal centrifugal	70,000	
103	R	Colusa Irrigation District	Electric	300	1	36"	Horizontal centrifugal	50,000	59,320
101.9	L	B. D. Beckwith	Electric	50	1	12"	Horizontal centrifugal	45,000	Idle
101	R	A. F. and R. O. Wahlfrom	Electric	75	1	18"	Horizontal centrifugal	10,000	440
99.8	L	D. George	Electric	50	1	12"	Horizontal centrifugal	4,500	700
99	R	Cheney Slough Project	Electric	300	1	36"	Horizontal centrifugal	34,000	
99	R	Cheney Slough Project	Electric	150	1	22"	Horizontal centrifugal	18,000	
99	R	Cheney Slough Project	Electric	200	1	26"	Horizontal centrifugal	20,500	87,133
96.8	L	J. K. Wenet	Electric	50	1	18"	Horizontal centrifugal	10,000	1,811
96.7	L	O. Poirier	Electric	75	1	15"	Horizontal centrifugal	7,000	988
96.8	L	Mrs. B. Graham	Electric	100	1	20"	Horizontal centrifugal	13,000	1,169

96.6	L	Mrs. B. Graham	Electric	75	1	18"	Horizontal centrifugal	4,500	760
96.6	R	I. G. Zumwalt	Electric	50	1	12"	Horizontal centrifugal	4,500	760
96.7	L	A. N. Lewis Estate	Electric	75	1	15"	Horizontal centrifugal	7,000	
96.7	L	W. B. Boggs	Electric	50					
94.6	R	W. M. Pinney	Electric	50	1	12"	Horizontal centrifugal	4,500	322
94.3	R	Tuttle & Tubbs	Electric	50	1	15"	Horizontal centrifugal	7,000	2,592
93.2	R	V. W. Brown	Tractor	40	1	12"	Horizontal centrifugal	4,500	235
92.5	L	Unknown	Tractor			6"	Horizontal centrifugal.		
91.4	L	Moulton Irrigated Land Company	Electric	100	1	20"	Horizontal centrifugal	11,000	2,353
90.5	R	Roberts Ditch Irrigation Company	Electric	100	1	20"	Horizontal centrifugal	13,000	4,727
89.8	R	Colusa City	Electric		1		Vertical plunger.		
89.6	L	T. H. Boggs	Electric	50	1	12"	Horizontal centrifugal	4,500	200
89.4	L	Burke & Mitchell	Electric	75	1	15"	Horizontal centrifugal	7,000	1,448
89.3	R	Colusa Irrigation Company	Electric	150	1	20"	Horizontal centrifugal	14,000	3,223
87.7	R	Sutton & Montgomery	Electric	50	1	12"	Horizontal centrifugal	4,500	333
87.3	R	Campbell & Dwyer	Electric	75	1	15"	Horizontal centrifugal	7,000	963
87	R	Campbell & Dwyer	Electric	75	1	15"	Horizontal centrifugal	7,000	1,649
86	R	Cal. Ewing	Electric	25	1	12"	Horizontal centrifugal	4,500	Idle
83.5	L	P. E. Garmire	Electric.						
81	R	A. Steidlmire	Tractor	75	1	12"	Horizontal centrifugal	4,500	33
80.1	L	Alameda Sugar Company	Electric	100	1	18"	Horizontal centrifugal	10,000	2,000
79.2	L	C. E. Reische	Electric	35	1	10"	Horizontal centrifugal	3,000	210
78.2	R	George Davis	Steam						Idle
78	L	E. V. Jacobs	Electric		1	12"	Horizontal centrifugal	4,500	80
76	L	J. H. Yates	Electric	35	1	10"	Horizontal centrifugal	3,000	122
73.3	R	E. B. Vann	Electric	50	1	12"	Horizontal centrifugal	4,500	200
71.8	R	Sacramento Valley Sugar Company	Electric	100	1	15"	Horizontal centrifugal	7,000	Idle
71.3	L	Alameda Sugar Company	Electric	100	1	18"	Horizontal centrifugal	10,000	Idle
71	R	Unknown	Electric	150	1	15"	Horizontal centrifugal	7,000	
70.7	R	Town of Grimes	Electric	5	1	4"	Vertical plunger		11
70.3	R	W. W. Kilgore	Electric	40	1	12"	Horizontal centrifugal	4,500	200
69.4	R	Faxon & Montague	Electric	75	1	18"	Horizontal centrifugal	3,000	1,007
69.1	R	J. W. Browning	Electric	150	1	30"	Horizontal centrifugal	30,000	2,600
66.9	L	Victor Massey	Gas	75	1	18"	Horizontal centrifugal	10,000	
64.4	L	Victor Massey	Gas	40	1	12"	Horizontal centrifugal	4,500	
63	R	W. M. Baker	Gas	16	1	18"	Horizontal centrifugal	1,600	
63.3	R	Reclamation District No. 108	Electric	100	1	26"	Horizontal centrifugal	30,000	4,266
63.3	R	Reclamation District No. 108	Gravity		6		Concrete culverts		17,762
60.3	L	A. Kimineerer			1	12"	Horizontal centrifugal.		
55.5	L	O. T. Spencer	Electric	75	1	20"	Horizontal centrifugal	14,000	
54.3	R	E. J. Miller	Electric	40	1	12"	Horizontal centrifugal	4,500	70
48.5	L	P. J. Hiatt	Electric	50	1	12"	Horizontal centrifugal	4,500	90
44.1	R	Reclamation District No. 108	Electric	150	1	8"	Horizontal centrifugal	32,500	2,502
43.2	R	River Garden Farms Company	Electric	250	1	26"	Horizontal centrifugal	25,000	3,333
37	R	River Garden Farms Company	Electric	75	1	15"	Horizontal centrifugal	7,000	467
37	R	River Garden Farms Company	Electric	125	1	20"	Horizontal centrifugal	14,000	2,432

(a) Location, in miles, by river from Sacramento city. (b) Power: Electric signifies electric-driven; gas = internal combustion engine; H. P. = horsepower. (c) Pumps: No. = number of pumps; Size = inches in diameter of discharge. (d) Division: The figures representing quantity diverted during the season of 1918 are from statements of owners or attendants.

THE DEBRIS PROBLEM.

The United States Debris Commission, created by the Caminetti Act of 1893, has already been referred to herein under the caption, "Sacramento River Problems."

The commission is composed of three officers of the Engineer Corps, U. S. Army, and its duties prescribed by the act are, briefly stated:

(1) To regulate hydraulic mining so as to prevent, in so far as practicable, debris reaching the navigable streams.
(2) To design and execute plans for the amelioration of conditions unfavorably affecting navigation in the streams under its charge.

Its jurisdiction extends to the entire drainage area of the Sacramento and San Joaquin rivers.

In pursuit of its duties under the first definition above, the commission prescribes regulations for the storage or control of debris from mines and issues licenses for their operation when the regulations are complied with, and revokes licenses already issued for violations of the conditions prescribed.

Performing the second duty prescribed, the commission devised measures for the arrest of an immense volume of debris lodged in the canyons of the Yuba, which in the natural course would eventually reach the Sacramento River, and formulated the plan for the control of floods, protection of lands, and improve navigable conditions in the Sacramento River. The plan has been fully described in previous reports of this department and referred to in a previous paragraph herein. (See Sacramento River Problems, *ante*.)

The report of the commission is made annually to the War Department and is published in the reports of the Chief of Engineers, U. S. Army.

The state has contributed one-half the cost of the works on the Yuba River and has adopted the plans for flood control and river improvement and contributed funds equal to the congressional appropriations for carrying out the plans.

The State Engineer is enjoined by law to co-operate with the Debris Commission in all matters wherein the state is concerned.

The work of improving inland waterways and assisting navigation thereon, other than in connection with debris control, is also delegated to army engineers and the reports of their operations appear in the report of the Chief of Engineers contemporaneously with the Debris Commission's report.

These reports contain a large amount of valuable and interesting information and this department has heretofore reproduced them in full, and it is keenly regretted that limitations placed upon the state's

publications restricts their appearance to a summary of their prominent features.

Owing to certain regulations of the War Department, information of a later date than June 30, 1917, is not available for publication at the time the text of this report is transmitted to the printer.

In the matters treated of and set forth in the summary of the reports to follow this, the Department of Engineering for the state has procured, or is negotiating for, rights of way and easements on the Sacramento and San Joaquin rivers and Stockton Harbor necessary for the work described in the reports and referred to in the summary.

SUMMARY OF REPORT OF DEBRIS COMMISSION JULY 1, 1915, TO JUNE 30, 1917.

During this period, the commission consisted of Col. Thomas H. Rees (senior member) to February 1, 1917; succeeded by Col. Edw. Burr (senior member); Major L. H. Rand (secretary), having immediate supervision of the work; Major Richard Park, Corps of Engineers.

1. Regulation of Hydraulic Mining.

From the date of its organization to June 30, 1916, the commission received 915 applications for licenses to operate hydraulic mines, and 90 licenses were issued. Prior to September 6, 1917, the commission had permitted brush and log crib dams to be constructed, but since then only dams of permanent construction have been allowed. During the year ending June 30, 1917, seven applications were received, making the total 922, five licenses issued and three revoked. Total number of mines operating, 14.

Hydraulic Dredges. Fifty-five hydraulic dredges, turning over 40,000,000 cubic yards of earth and gravel a year, are mining for gold along the streams. Of these, four are operating under permits issued by the Secretary of War. All dredges are required to prevent their debris reaching the streams.

Quartz Mills. Tailings from mills crushing quartz for the extraction of metals, particularly gold and copper, sometimes are washed into the navigable waters. Owners are, therefore, required to impound the tailings or debris. Twelve mills were required to take steps to care for their debris.

Illegal Mining. Very few hydraulic mines are reported as violating the law by operating without license. Two cases were reported to the federal grand jury, resulting in one indictment. The accused pleaded guilty in the United States Court and was fined.

2. Studies and Reports.

Survey of the Sacramento above Chico Landing was commenced in May, 1916, and general studies continued of the other streams affected by the debris. Projects for reclamation conducted under the supervision of the State Reclamation Board have been examined to see that they conform to the great flood control project. The expenses of the commission's operations under 1 and 2, above, were $14,977.59 in 1915–16, and $15,340.72 for the fiscal years 1916–17. The entire cost is borne by the government. The total appropriations for these purposes to June, 1917, amounts to $304,001.98.

3. Yuba River.

The project to hold and control the large accumulation of debris in this stream consists of a barrier across the mouth of the cañon, impounding a large volume of debris; the construction of an artificial channel for the river through Daguerre Point; construction of training walls from the Daguerre Point Cut to the confluence with Feather River at Marysville, so as to confine the Yuba River to a defined channel through an immense bed of debris. A fund of $800,000 was created for this project, the state and Congress each contributing $400,000.

Repairs and improvements were made to the inlet wall in Daguerre Point Cut; protective revetment placed at points on the training walls where being eroded; 2,200 feet of additional training walls above Daguerre Point Cut partly completed; embankments constructed across some high-water channels diverting from the river; the prescribed channel way from the lower end of the training walls to Marysville cleared of snags, trees and brush, and some blasting of hardpan done to expedite the deepening of the channel by scouring. Surveys were made to determine the effects of the works on the river.

The expenditures itemized for the two years aggregate $23,897.09, which leaves a balance of $88,569.20 in the co-operative fund July 1, 1917.

4. Sacramento and Feather Rivers.[1]

Operations for the alleviation of debris conditions in the Sacramento and Feather rivers have been conducted under joint agreements between the state and government. The original estimate for this work was $800,000, but changed conditions have caused a revision of the estimate to $1,660,000, not including rights of way and easements, or maintenance. The appropriations to date amount to $1,360,000, each participant contributing one-half.

Operations on the Lower Sacramento. During the two years 1916–17, the two hydraulic dredges, Sacramento and San Joaquin, belonging to the project, were continued in operation, removing 14,973,262 cubic yards of material from the river channel, at an average cost of 3.1 cents a cubic yard. A hired bucket dredge was employed to breach old levees and to construct embankments for retaining spoil deposits. This machine handled 1,001,782 cubic yards at a cost of $31,913.60, or at an average cost of 3.2 cents a cubic yard.[2]

The cost of the project to June 30, 1917, amounted to $1,353,936.53, including $444,253.90 paid for the two dredges and their equipment.

5. Control of Floods, etc.

A map was prepared showing lands required for cutoff across the bend at Collins Eddy, contemplated in the flood control plan. It is estimated that the excavation will cost $38,000[3]. Maps were also made showing lands required for the operations on the lower project. None of these maps have been published.

IMPROVEMENT OF SACRAMENTO AND FEATHER RIVERS AND SAN JOAQUIN RIVER AND TRIBUTARIES.

Sacramento River.

Sacramento-Feather Rivers Board. This board, appointed by the Secretary of War, under authority of the Rivers and Harbor Act, June 3, 1896, has charge of the improvement of the Sacramento and Feather rivers. The personnel is the same as that of the Debris Commission, with Major Rand as executive officer, who exercises immediate supervision of the work.

Sacramento River. The project is to maintain navigable depths from the mouth of the river to Sacramento City, 60.7 miles; 4 feet between Sacramento and Colusa, 90 miles; 3 feet to Chico Landing, 51.3 miles, and such depths as are practicable 51.6 miles to Red Bluff, 254.4 miles from the mouth. These results are to be obtained by a system of wing dams to concentrate the low water flow, by snagging and by occasional dredging.

It has been recommended that the channel depth to be attained be increased from 7 to 9 feet below Sacramento City.

Operations. During the two years, July 1, 1915, to June 30, 1917, snagging operations were carried on from the mouth to Tehama above Chico Landing, involving the

[1]Operations beneficial to Feather River were confined to the work on Yuba River noted under 2 above.

[2]The Department of Engineering invites attention to these costs of dredger work in contrast with the prices usually paid on contracts.

[3]This cutoff has been completed since the report.

removal from the river and destruction of snags, removal of overhanging trees from the banks and destruction of drift logs and trees lodged on banks and bars. The total removals were as follows:

	1916	1917
Snags	1,975	3,046
Trees	1,341	2,771
Drifts	----	1,635
	3,316	7,452

The cost of removing these obstructions, aggregating 10,768 in number, was $64,257.43.

Six new wing dams were constructed and repairs made to 39 others.

Dredging was necessary both seasons, both below and above Sacramento, which was done with dredges hired for the purpose. Snagging is done by a government snag boat.

Soundings were made and platted for progressive record of conditions in the river.

Survey Above Chico Landing. The river and harbor act approved March 4, 1915, directed a survey to be made of the Sacramento River from Chico Landing to Red Bluff. This was done and the district officer reported, recommending that no further attempts be made to improve the river above Chico Landing. (House Document No. 1893, 64th Cong., 1st Session.)

Financial Summary. Total appropriations to June 30, 1914, $1,327,000. Amount expended on *all* projects to June 30, 1917, exclusive of receipts from sales, etc., formerly included, amounting to $1,942.07:

New work	$37,212 71
New work and maintenance	[a]738,918 14
Maintenance	459,786 85
Total expended	$1,235,917 70

It is estimated that the state of California, the city of Sacramento and reclamation interests have expended approximately $3,000,000 in work beneficial to navigation.

Effect of Improvement. The effect of the improvement is that there is continuous navigation from the mouth of the river to Chico Landing. From San Francisco to Sacramento there are four daily (except Sunday), one weekly, and two semiweekly steamers. To Colusa, there are four weekly steamers, and to Chico Landing one weekly steamer from San Francisco. A gas passenger launch runs daily between Sacramento and Antioch and Stockton.

One hundred fifty-seven registered vessels and 101 unregistered of all kinds, steamers, gas boats (including tow boats), launches, gas schooners, sailing vessels and unrigged vessels, such a barges, dredges, etc., ply upon the Sacramento River either regularly or as occasion requires.

Traffic Statistics. In 1915 there were 766,935 tons of freight carried on the Sacramento River, and in 1916 there were 875,780 tons transported. The record for five years appears as follows:

Year	Short tons	Value
1912	477,292	$27,755,325
1913	733,594	35,856,791
1914	721,090	38,211,760
1915	766,935	38,027,703
1916	875,780	46,908,093

All of the river which is used for navigation is under improvement, hence all the traffic is considered as being affected by the improvement.

Feather River.

Project of Improvement. Work by the government for improvement of Feather River was discontinued in 1899[b] "until the flow of sand and other mining detritus from Yuba and Bear rivers is stopped." The river and harbor act approved July 27,

[a] Cost of new work and maintenance were not kept separate prior to March 3, 1899.
[b] Annual report Chief of Engineers, U. S. Army, 1899, page 3171.

1916, appropriated $10,000 for improvement of this river, contingent upon a like sum being furnished by local interests. Those conditions were met.[5] The plan of improvement is to make a depth of 2.5 feet available at low-water stage, from Marysville to the mouth of the river at Vernon, a distance of 28.3 miles.

Operations. During the fiscal year ending June 30, 1917, work of clearing the channel was conducted, in which obstructions were removed as follows:

Snags	190
Overhanging trees	487
Drifts	171
Total	848

This work cost $1,259.71. Surveys and soundings of portions of the river were made and platted at a cost of $175.

Local Co-operation. Considerable work has been done by local interests in construction of training walls, barriers, bank protection and snagging, and the erection of terminal facilities at Marysville.[6] It is estimated that about $1000 has been expended.

Commercial Statistics. A table showing traffic on the river is presented as follows:

Year	Short tons	Value
1912	2,729	$159,016
1913	3,332	207,366
1914	----	------
1915	2,906	------
1916	392	------

The slump in tonnage in 1916 is attributed to several causes—a strike of river men, delay in getting harvests to the river before the low water, etc.

San Joaquin River.

Projects. The general project extends from the mouth to Hills Ferry, 128.5 miles, and embraces several projects for improvement, including a channel depth of 9 feet below Stockton and improvement by cut-offs; improvement of Stockton, Mormon and Fremont channels and McLeod Lake, all parts of Stockton Harbor; the improvement of the river above Stockton, and maintenance of the Mormon Slough—Calaveras Diverting Canal.

The 9-Foot Channel. The lower 34 miles of the river has always been more than the required depth. Stockton Channel 2½ miles and San Joaquin River 8½ miles required deepening. Below Stockton there had previously been made thirteen river-bend cut-offs, three by the state and two included in the 9-foot project. The elimination of the bends shortened the channel distance 6 miles, increased the scouring effects of the tide and reduced the flood plane.

Upper River Channel. From Stockton to Hills Ferry is 83.3 miles, to which point the river is navigable for boats of 5 feet draft from about April to August.

In 1915–16 the government snag boat Seizer was employed in snagging from Stockton to Patterson Landing, 64 miles. The following year snagging operations were conducted by a crew operating from a houseboat. The territory covered was from the San Joaquin River (Southern Pacific Railroad) bridge to Patterson Pump, a distance of about 50 miles.

Dredging Below Stockton. During the two years Cut-off "C" was completed by the dredging of 40,200 cubic yards of material. Cut-off "B" was made with one of the Sacramento River dredges transferred for that purpose. In making the cut-off, 433,925 cubic yards were removed at a cost of $14,989.26 (3.45 cents a yard). These two cuts shorten the channel .93 mile.

[5] $5,000 were allotted from the Department of Engineering river fund and Sutter and Yuba counties contributed $2,500 each.

[6] The Department of Engineering had endeavored to improve conditions by training walls and snagging, removing more than 1,000 snags in one season. The result was that steamers were able to reach Marysville until August, which accounts for the figures of traffic in the table. Extremely low water after the department ceased work interfered with traffic.

The lower 3000 feet of Stockton Channel and the river for 2500 feet below the junction were dredged to a depth of 9 to 10 feet and 100 feet wide. The work was done by a suction dredge under contract at 18.4 cents a cubic yard. The total cost, including superintendence, inspection, etc., was $12,050.05.

Contracts were let for dredging at several points below Stockton, and one subdivision of the work completed.

Surveys. Surveys and office work were executed in preparing maps and descriptions for further improvement along Stockton Channel and the river for 10 miles below the city.

Expenditures. The expenditures for the fiscal years 1915–16 and 1916–17 were:

For the San Joaquin River, 9-foot project	$29,963 96
For Stockton Harbor channels	20,033 95
Total	$49,997 91

Results of Operations. The results of the operations recited are:

The river is navigable to Hills Ferry, 128½ miles from the mouth, for boats drawing 5 feet until about August;

The harbor of Stockton has a governing depth of 9 feet, excepting Mormon Channel, which is 4 feet deep;

The river below Stockton has a general depth of 9 feet. The cut-offs have shortened the channel length, eliminated many short bends, thus lessening danger in foggy weather, and stabilized running schedules in addition to lowering the flood plane and increasing the deepening action of tidal currents.

Appropriations. The appropriations and allotments made by the government for the purposes discussed, from 1876 to June 30, 1917, were as follows:

For San Joaquin River, 9-foot project	$169,632
For Stockton Harbor channels	722,170
Total	$891,802

Commercial Statistics. The vessels using the San Joaquin River are classified as follows:

Registered steamers	20	
Gas boats	85	
Sailing	25	
		130
Unregistered gas boats	14	
Sail	2	
Unrigged	54	
		70
Total		200

In 1915, boats on the river carried 831,234 tons of freight, and in 1916 there were 824,222 tons transported. The record of river transportation for five years appears as follows:

Year	Short tons	Value
1912	632,591	$38,854,539
1913	820,399	38,341,174
1914	772,156	35,479,741
1915	831,234	36,358,240
1916	824,222	42,179,160

Mormon Slough-Calaveras Diverting Canal.

The Project. This canal was constructed some years ago to divert the waters of Mormon Slough around north of Stockton into Calaveras River to prevent them carrying sand and detritus into Mormon Channel and the San Joaquin, at Stockton.

Operations for the Years 1915–17. The work has consisted of clearing a growth of brush from the channel of Calaveras River and the canal. It was done by hired labor at a cost of $3,983.19. The total expenditures to June 30, 1917, was $250,477.58.

Co-operation. It was required that right of way should be furnished free, which was done by the state and the city of Stockton, jointly.

Effect of Improvement. The deposits in Stockton and Mormon channels since the completion of the canal have been less than formerly. It is quite certain that without the canal the flood of 1911 would have caused great damage to navigation.

Mokelumne River.

Existing Project. The object of the project is to maintain navigable depths as follows:

	Depth	Miles
From the mouth of river to the confluence of North and South Forks	9	4
North Fork, from confluence to Snodgrass Slough	9	8
From Snodgrass Slough to forks of river	6	1
South Fork, from junction to forks at Newhope Landing	9	14
From Newhope Landing to Galt-Newhope Bridge	3	8

Operations. A clam-shell dredge was hired a short time each year in removing a shoal and bar near Newhope Landing, increasing the depth from 3½ to 6 feet. The total cost was $1,359.75.

Local Co-operation. Appropriation acts in 1892 and 1894 stipulated that a certain drainage canal near Newhope Landing should be closed, which was done. About 1904 the state spent $10,000 and private parties claimed to have expended $40,000 on improvement. In 1910 the state of California spent $22,782.39 on improvements. Additional work done in 1911 by private parties.

Commercial Statistics. The record of traffic on the river for five years is as follows:

Year	Short tons	Value
1912	50,443	$2,833,704
1913	90,585	5,079,932
1914	69,783	3,045,870
1915	88,624	4,033,698
1916	80,871	5,202,847

Appropriations and Expenditures. The total appropriations from 1884 to June 30, 1917, were $32,500, and the total expenditures for the same period were $31,500.

WATER RESOURCES.

Investigation, measurement and cataloging of the water resources of the state have been diligently prosecuted for many years by private interests seeking to take advantage of the loose laws to appropriate the waters to private exploitation.

It was not until recent years that the public awoke to the fact that the vast resources of the state, residing in the potential waters of its rivers, brooks and waterfalls, its lakes and glaciers, were fast passing to private ownership, and interposed a staying hand by enacting the conservation laws of 1911.

The government had been engaged in a small way in gathering data as to stream flow, but not until co-operation was established with the state did this character of research assume a degree of activity at all in keeping with its importance to the public.

When the Department of Engineering was created and entrusted with the task of representing the state in these matters, the work of gathering

NOTE.—The state expended $60,000 and the city of Stockton about $26,000 in obtaining rights of way for the diverting canal.

information began to expand, and by 1909 there were 70 gaging stations established on the streams of the state. That was not many when the extent of territory and mileage of stream is considered, but by co-operating and uniting the funds of state and nation the work was prosecuted and data began to accumulate.

Records of stream flow are highly important, indeed absolutely necessary, in devising projects for irrigation, reclamation, flood control, power development, and navigation, or in fact any use to which flowing water may be devoted. The lack of complete records is keenly felt by the Department of Engineering and all others in attempting to solve the many problems of hydroeconomics so vital to the prosperity of the state.

The need for correct information concerning stream flow was never more clearly manifested than in the preparation of plans for the control of floods and reclamation of overflowed lands in Sacramento Valley. A comprehensive scheme was worked out from the best data extant at the time by eminent men who had had great experience in such matters in the Mississippi Valley. This was before the government and the state had inaugurated extensive investigations.

Work on small units of the plan had been started when it was discovered by actual measurements that the quantity of water to be cared for was *four times* as much as the proposed works were intended to handle.

The works now being constructed will control five times as much water as had been thought could be the possible maximum.

The failure of many irrigation enterprises for lack of water after large sums had been expended in constructing works, tells sadly of the lack of information which the co-operating agencies of the nation and state are sedulously engaged in gathering.

In addition to the arrangement whereby the United States and the state jointly measure the streams, the co-operation of individuals, corporations and municipalities having interest in certain streams is enlisted, thus enabling a much larger field to be covered than would be possible with the funds appropriated.

The last report showed that at the close of the fiscal year, June 30, 1916, there were 168 gaging stations being maintained. Since then 39 of these stations have been abandoned and 49 new ones established. Some of the abandonments were due to the withdrawal of private co-operation, but most of them because of the unimportance of the streams, or for the reason that a record had been completed for a period long enough to furnish a reliable rating for the stream.

The results of the observations at the gaging stations established at various points on the streams of the state are published from time to time in the bulletins issued by the Geological Survey under the title of Water Supply Papers.

These published records give the following information:

Description of station, and of its characteristics.
List of discharge measurements, made on the stream above.
Table of daily gage heights at the station.
Table of daily discharges.
Table of monthly and yearly discharges and run-off.

The methods employed in making the measurements have been described in previous reports of this department and are so graphically set forth in the water supply publications that they need not be described here.

The investigations into the water resources of the state by the United States Geological Survey in co-operation with the state of California during the last biennial period have been conducted under the charge of Mr. N. C. Grover, chief hydraulic engineer, chief of the water resources branch, United States Geological Survey, by Mr. H. D. McGlashan, district engineer, whose report here follows:

REPORT TO THE DEPARTMENT OF ENGINEERING ON THE PROGRESS OF THE CO-OPERATIVE SURFACE WATER INVESTIGATIONS IN CALIFORNIA BY THE WATER RESOURCES BRANCH OF THE UNITED STATES GEOLOGICAL SULVEY FOR 1916-1918.

The co-operative investigation of the surface water resources of the state of California during the past two years has been maintained on practically the same basis as in former years. While the number of river measurement stations in actual operation has not materially changed during this period, it has been necessary to discontinue a few stations and establish several new ones to meet the special needs of the state. Numerous improvements have been made in station equipment which materially increase the accuracy of the records. The apportionment of the work throughout the several drainage basins has remained practically unchanged, except in the Great Basin drainage. In this area a number of new stations have been established, at the request of the Department of Engineering and the State Water Commission, in order to determine the water supply available for proposed irrigation districts in Surprise Valley and Honey Lake Basin.

The following table shows the river measurement stations maintained during the two-year period ending October 31, 1918. This list does not include stations maintained by private parties, for which complete records are furnished for publication in our Annual Progress Reports. The regular stations are distributed among the major drainage basins of the state, as follows: Sacramento, 17 per cent; San Joaquin, 32 per cent; South Pacific, 23 per cent; North Pacific, 8 per cent; Great Basin, 20 per cent.

Stream	Post Office
Alameda Creek	Niles
Alameda Creek	Alvarado
American River	Fairoaks
American River, Middle Fork	East Auburn
American River, North Fork	Colfax
American River, South Fork	Placerville
Arroyo Seco	Pasadena
Arroyo Seco	Soledad
Baxter Creek	Lassen
Bear Creek*	Springville
Bear River	Colfax
Bear River	Van Trent
Bidwell Creek, near	Fort Bidwell
Bidwell Creek, at	Fort Bidwell
Boulder Creek	Julian
Box Canyon Creek	Fort Bidwell
Cache Creek	Yolo
Calaveras River	Jenny Lind
Carson River, East Fork	Markleeville
Carson River, West Fork	Woodfords
Cherry Creek	Sequoia
Clear Lake	Lakeport
Cooks Lake	Fort Bidwell
Cowhead Lake	Fort Bidwell
Cosumnes River	Michigan Bar
Cosumnes River, North Fork	El Dorado
Coyote River	Madrone
Coyote River	Coyote
Coyote River	Edenvale
Coyote River*	San Jose
Cuyamaca Water Company's flume, at diverting dam	Lakeside
Cuyamaca Water Company's flume*	Lakeside
Deep Creek, above Dismal Creek	Warner Lake, Ore.
Deep Creek, below Dismal Creek	Warner Lake, Ore.
Deep Creek	Adel, Ore.
Deer Creek	Hot Springs
Dismal Creek	Fort Bidwell
Eaton Creek	Pasadena
Eel River	Scotia
Eleanor Creek	Sequoia
Elsinore Lake	Elsinore
Escondido Mutual Water Company's canal	Nellie
Falls Creek	Sequoia
Feather River	Oroville
Feather River, Middle Fork	Oroville
Feather River, Middle Fork	Sloat
Feather River, South Fork	Enterprise
Fifteen Mile Creek	Warner Lake, Ore.
Fish Creek	Duarte
Fresno River	Knowles
Fresno Flume and Lumber Company's flumes	Shaver
Gobernador Creek	Carpinteria
Golden Rock Ditch*	Sequoia
Goodyear Creek	Goodyear Bar
Haines Creek	Tujunga
Hat Creek*	Hat Creek
Horse Creek, East Fork	Fort Bidwell
Horse Creek, West Fork	Fort Bidwell
Indian Creek*	Crescent Mills
Indian Creek	Happy Camp
Janesville Creek	Lassen
Kaweah River	Three Rivers
Kaweah River, North Fork	Kaweah
Kaweah River, South Fork	Three Rivers
Keeno Creek	Fort Bidwell
Kern River	Kernville
Kings River	Sanger
Klamath River	Selad Valley
Klamath River	Requa
Kosk Creek*	Henderson
Laguna Seca	Coyote

*Discontinued.

Stream	Post Office
Little Santa Anita Creek	Sierra Madre
Long Valley Creek	Scotts
Long Valley Creek	Doyle
Markleeville Creek, above	Markleeville
Markleeville Creek, at	Markleeville
McCloud River	Baird
Merced River, Happy Isles	Yosemite
Merced River*	Yosemite
Merced River, Pohono Bridge	Yosemite
Merced River	Exchequer
Merced River, South Fork	Wawona
Middle Eel River	Covelo
Modesto Canal	La Grange
Mokelumne River	Clements
Mokelumne River, Licking Fork*	Railroad Flat
Mokelumne River, Middle Fork	West Point
Mokelumne River, North Fork	West Point
Mokelumne River, South Fork	Railroad Flat
Mono Lake	Mono Lake
Monrovia pipe line	Monrovia
Oakdale Canal	Knights Ferry
Oregon Creek	North San Juan
Owens Lake	Lone Pine
Owens River	Round Valley
Owens River	Big Pine
Owens River	Lone Pine
Pacoima Creek	San Fernando
Palermo Land and Water Company's canal	Enterprise
Pine Creek	Alturas
Pine Creek	Round Valley
Pit River	Henderson
Pit River	Ydalpom
Putah Creek	Winters
Reeve-Davis ditch*	Happy Camp
Rock Creek	Fort Bidwell
Rock Creek	Goodyear Bar
Rock Creek	Round Valley
Rogers Creek	Azusa
Sacramento River	Castella
Sacramento River	Red Bluff
Salton Sea	Salton
San Antonio Creek	Claremont
San Diego*	Lakeside
San Diego River	Santee
San Diego River*	San Diego
San Dieguito River	Barnardo
San Dimas Creek	San Dimas
San Gabriel River	Azusa
San Jacinto River	Elsinore
San Joaquin River	Friant
San Joaquin River	Newman
San Luis Rey River	Mesa Grande
San Luis Rey River*	Nellie
San Luis Rey River*	Pala
San Luis Rey River	Bonsal
Santa Ana River	Mentone
Santa Anita Creek	Sierra Madre
Santa Maria Creek	Ramona
Santa Ynez River	Santa Barbara
Santa Ynez River	Lompoc
Santa Ysabel Creek	Mesa Grande
Santa Ysabel Creek	Ramona
Sawpit Creek	Monrovia
Schloss Creek	Lassen
Scott River	Callahan
Scott River, East Fork	Callahan
Shasta River	Montague
Smith River, Middle Fork	Crescent City
Smith River, North Fork	Crescent City
South San Joaquin Canal	Knights Ferry
Southern California-Edison Company's Canal	Azusa

*Discontinued.

Stream	Post Office
Southern California-Edison Company's Canal	Mentone
Spanish Creek	Keddie
Stanislaus River	Knights Ferry
Stanislaus River, North Fork	Avery
Stanislaus River, South Fork*	Strawberry
Stevenson Creek	Shaver
Susan River	Susanville
Sweetwater River*	Dehesa
Sweetwater River	Descanso
Tenaya Creek	Yosemite
Temescal Creek	Elsinore
Trinity River	Lewiston
Trinity River	Hoopa
Tujunga Creek	Sunland
Tulare Lake	Stratford
Tule River	Porterville
Tule River, South Fork	Porterville
Tuolumne River, below Hetch Hetchy damsite	Sequoia
Tuolumne River	Buck Meadows
Tuolumne River, above La Grange Dam	La Grange
Tuolumne River, at La Grange Dam	La Grange
Tuolumne River, Middle Fork	Buck Meadows
Tuolumne River, South Fork	Sequoia
Tuolumne River, South Fork	Buck Meadows
Turlock Canal	La Grange
Twelve-Mile Creek	Fort Bidwell
Twenty-Mile Creek	Warner Lake, Ore.
Utica Gold Mining Company's canal	Avery
West Walker River	Coleville
Yosemite Creek	Yosemite
Yosemite Power Company's canal	La Grange
Yuba River	Smartsville
Yuba River, Middle Fork	North San Juan
Yuba River, North Fork	Goodyear Bar
Yuba River, North Fork, North Fork	Downieville

*Discontinued.

The above work has been maintained in accordance with co-operative agreements with the state of California, through the Department of Engineering and the State Water Commission; with the city and county of San Francisco, through M. M. O'Shaughnessy, city engineer; with Los Angeles County, through the board of supervisors, and with the U. S. Forest Service and the National Park Service. In addition, substantial assistance has been furnished by other federal bureaus and by state, county and municipal officers, irrigation districts, private companies, and individuals. The amount of work done and its cost, including estimated expenditures for complete records furnished free for publication, for the two-year period ending June 30, 1918, was as follows:

Drainage	Number of stations			Number of discharge measurements				Average annual cost per station, including new construction and office work
	Established	Discontinued	Maintained June 30, 1918	At regular stations	Miscellaneous	Total	Average at each station per year	
Sacramento	5	3	35	483	56	489	6	$164 00
San Joaquin	8	20	54	702	93	795	6	198 00
South Pacific	12	9	38	1,201	428	1,629	16	397 00
North Pacific	1	1	12	83	24	107	3	114 00
Great Basin	23	6	39	482	120	602	10	117 00
Totals	49	39	178	2,901	721	3,622	8	$198 00

The following Surface Water-Supply Papers, containing California records, have been published since November, 1916:

Paper 361, Annual Progress Report of California for the year ending September 30, 1913.

Paper 390, Annual Progress Report of Great Basin for the year ending September 30, 1914.

Paper 391, Annual Progress Report for California for the year ending September 30, 1914.

Paper 426, Southern California Floods of January, 1916.

Water-Supply Papers 410, 411 and 441, for the years 1915 and 1916, have been approved for printing and are expected to be available for distribution in a short time. All records for the year ending September 30, 1917, have been compiled and the results are available to the public. They will be published in Water-Supply Papers 460 and 461. Also this office has in preparation a special Southern California Report which will include all stream flow records collected by the Geological Survey in this section of the state.

In the administration of the work of the Water Resources Branch of the Geological Survey, the district office is maintained at 328 Custom House, San Francisco. A suboffice is retained at 619 Federal Building, Los Angeles, for the convenience of southern California. Data collected by all branches of the Geological Survey may be consulted at either office.

GROUND WATERS.

In few localities of the state are conditions so well adjusted that the surface waters are sufficiently under control as to adequately serve all the lands within their reach. In some localities no surface water at all is available.

Fortunately in many localities where the streams are wanting or inadequate, there are underground waters which may be obtained for irrigation, either supplemental to the surface supply, or in the latter's absence in lieu thereof.

Throughout the great desert region of the state lying to the east of the mountain ranges are small bodies of fertile arid land underlain at varying depths with water which can be made available for surface use by means of wells and modern pumping methods. Considerable areas have been brought under cultivation by these means. Such underground waters are also being developed in the most barren and forbidding portion of the desert and used for washing out gold by the hydraulic process.

The desert is rich in mineral resources, metals in the hills and potash, soda, borax, and other salts in the beds of dried-up lakes. The scarcity of water retards the development of the known deposits and ignorance of the location of infrequent springs and water holes on the part of miners, prospectors and explorers claims a toll of death every year.

Special effort has been put forward in late years by the co-operative agencies of nation and state to locate all waters, determine their quality for use, to mark their positions on maps and erect guideposts directing the thirsty traveler to them.

From August, 1917, to March, 1918, the desert survey covered more than 30,000 square miles, during which 356 guide signs were erected.

During the past biennium, as before, the ground water investigations were conducted by Mr. O. E. Meinzer, geologist in charge, Ground Water Division, under the direction of N. C. Grover, Chief Hydraulic Engineer. Mr. Meinzer's report is as follows:

REPORT TO THE DEPARTMENT OF ENGINEERING ON THE PROGRESS OF THE GROUND-WATER INVESTIGATIONS IN CALIFORNIA BY THE WATER RESOURCES BRANCH OF THE U. S. GEOLOGICAL SURVEY FOR 1916-1918, BY O. E. MEINZER, GEOLOGIST IN CHARGE, DIVISION OF GROUND WATERS.

The most important new project that was undertaken in the last biennial period was a survey of desert watering places throughout an area of 30,000 square miles, extending from the Mexican border northward to the southern part of Death Valley, by D. G. Thompson and J. S. Brown. The field work was begun in August, 1917, and completed in March, 1918. Most of this region was mapped by plane-table methods on a scale of 1:125,000. Nearly all watering places in the region were examined and samples for analysis were taken from many of them. Guides to watering places in this region are being prepared for publication. These guides will contain dependable maps showing the relief and the locations of the watering places and connecting roads. Signposts directing to watering places were erected at 167 localities, the total number of sign plates erected being 356.

On account of the conditions produced by the war, the field work on desert watering places could not be continued through the year 1918, but it is hoped that after the war it will be possible to extend this work over the rest of the desert portions of the state, and to make a resurvey of the desert region at regular intervals in order to keep the maps and signboards up to date and to make necessary repairs on existing signboards. The experience of the last year has shown that this work can be completed and maintained at very moderate cost. It is believed that its value to the people of the state is out of all proportion to its cost.

In 1918 a large part of the ground-water work in the state was done for the purpose of assisting the War and Navy departments of the federal government in developing the largely increased water supplies that were made necessary by the war. This war work was, of course, given preference over all other investigations.

A report on the ground-water supply for irrigation in the Morgan Hill area in Santa Clara Valley, by W. O. Clark, has been published as Water-Supply Paper 400-E.

A report on ground water in San Jacinto and Temecula basins, by G. A. Waring, has been completed and is now in press as Water-Supply Paper 429.

A comprehensive report on the geology and ground water resources of the western slope of San Diego County, by A. J. Ellis and C. H. Lee, has been completed by the authors and is in process of publication as Water-Supply Paper 446.

A final report on ground water in Sacramento Valley, by Kirk Bryan, has also been completed and is in process of publication.

The final report on ground water in Santa Clara Valley, by W. O. Clark, is nearly completed. Measurements are being continued on water levels in wells in order to estimate the annual recharge, and records of stream flow are being obtained at several points on Coyote Creek in order to ascertain the amount of water that seeps into the ground and thus to obtain a check on the estimates based on fluctuations of water levels in wells.

A survey was begun by W. O. Clark of the ground water in Salinas Valley. The field work in this valley has been nearly completed but the report based on this field investigation has not yet been prepared.

A reconnaissance survey of ground water conditions in Pahrump, Mesquite, Ivanpah and Lanfair Valleys was made by G. A. Waring and D. G. Thompson, the results of which are to be published as a contribution to hydrology. A part of the area occupied by these valleys lies in Nevada.

A reconnaissance survey was also made by Messrs. Waring and Thompson of the ground water conditions in Mohave Valley and in several smaller valleys in the same region. The results of this survey are also to be published as a contribution to hydrology.

In connection with the desert watering-place survey by J. S. Brown, data were collected on artesian water conditions and on the prospects of developing additional ground water supplies in Imperial Valley near the Mexican border.

Since 1900 measurements of depths to water levels in a series of wells in southern California have been made at intervals for the purpose of obtaining a record through many years of the relation between the contribution to the ground water reservoirs during the rainy seasons and the withdrawals from them during the dry seasons when ground water is pumped for irrigation and is withdrawn in large quantities by evaporation and transpiration. Most of the records for the period prior to 1909 have been published in Water-Supply Papers 213 and 251. The records for 1909, 1910, and 1912, together with a brief discussion by W. C. Mendenhall, were published in Water-Supply Paper 331. The work is at present being carried on by F. C. Ebert, who is tabulating all available water level data of the region for publication in a water-supply paper.

IRRIGATION INQUIRY.

Under authority of the law establishing the Department of Engineering and prescribing its duties, agreements are entered into by the State Engineer and the United States Department of Agriculture for the co-operative investigation of problems connected with irrigation. The United States is represented in these matters by the Irrigation Division, Bureau of Public Roads, U. S. Department of Agriculture.

Mr. Frank Adams, Irrigation Manager, has continued in charge of the work, which is under the direction of Dr. Samuel Fortier, chief of the division. Mr. Adams' detailed report will be found under appropriate heading.

In former reports of this department, it has been repeatedly held that when irrigation shall come to be scientifically applied it will be found that in many cases a lesser quantity of water will accomplish full benefits, and if the application were restricted to actual requirements there would be a saving of water that could be applied to other lands.

The experiments on the State Farm at Davis have demonstrated that under the conditions of soil, climate and cost of water obtaining at that place, the application of more than 30 inches in depth of water to alfalfa is unprofitable, and that when 48 inches or more is applied, an actual loss occurs. Yet there are fields of alfalfa where natural conditions are similar to those at Davis, upon which water is used in greater quantities, entailing a substantial, even though unsuspected, loss of production.

PLATE IX.

Upper figure.—Concrete weir on Cross Creek built by Lake Lands Canal Company for diverting water into Lake Lands Canal under war emergency stipulation permitting temporary diversions of Kings River flood waters.

Lower figure.—Barley field on San Luis Obispo sewage farm.

PLATE X.

Upper figure.—Portion of State Land Settlement Project at Durham.
Lower figure.—Proposed dam site for Pine Flat reservoir contemplated by Kings River Conservation Association.

Such excessive use of water is mostly due to lack of knowledge of crop requirements, which knowledge it is a function of the co-operative research being conducted to ascertain and publish. It goes without saying that when the irrigator becomes convinced that he can do better with less water than he has been accustomed to use, he will reform his practice.

A careful reading of the report is commended. It will be noted that already a marked increase in the duty of water for irrigation of rice is apparent. In localities where formerly 7.25 feet of water were used, results equally as good were later obtained with the application of 5.50 feet.

Several instances are cited wherein claimants of water which had not been theretofore fully utilized were induced from patriotic motives to release a portion of that water for the production of war crops on others' lands, thus making a considerable addition to food production without great injury to those who temporarily released the water.

The success of the efforts along this line as detailed in the report prompts the author to observe that it "indicated in a broad, general way that large opportunities exist for co-ordination of effort and reduction of waste arising from nonuse or misuse of irrigation water." He believes that through the efforts of the several agencies engaged, there was a more complete and more economical use of irrigation water than in any previous year, and is moved to ask: "When the war emergency is passed, can public sentiment be kept up to the point of holding to the principles found workable in 1918?" He recommends that a way be found to continue the effect of the emergency order of the Railroad Commission and the emergency act of the 1917 legislature under which these savings were accomplished.

The Department of Engineering believes that public sentiment can be so held, but holding to the "principles found workable" is a matter of education, and to educate the public, *i. e.*, the water-using public, to accept those principles is the object sought to be accomplished by the co-operative research under discussion.

The question now arises: Is not this matter of sufficient importance to warrant more activity in educational effort to inculcate the principles referred to? All of the co-operating agencies are anxious to extend their work, and are held back only by lack of funds.

This matter is commended for earnest consideration, and appeal made for adequate appropriation to enable the work to be vigorously prosecuted.

Some features of the report may be hereinafter referred to, but anticipating that the reader will give careful perusal to the entire report, further comment at this time is withheld and the report presented in full, as follows:

PROGRESS REPORT OF CO-OPERATIVE IRRIGATION INVESTIGATIONS IN CALIFORNIA, 1916-1918.

By FRANK ADAMS, Irrigation Manager.

Introduction.

During the past two years principal co-operating agencies in irrigation investigations in California have continued as heretofore, namely: Irrigation Investigations, now designated as Irrigation Division, U. S. Department of Agriculture; California State Department of Engineering; College of Agriculture of the University of California; and California State Water Commission. In special studies of rice irrigation we have continued to work with the Biggs Rice Experiment Station of the Cereal Investigations, Bureau of Plant Industry, U. S. Department of Agriculture. In studies of irrigation problems of particular communities, we have considerably increased co-operation with the farm advisers and farm bureaus of a number of the counties, chiefly Shasta, San Joaquin, El Dorado, Merced and Kern. In connection with increased food production in the interest of the war emergency a substantial measure of co-operative effort has been carried on with the United States Food Administration for California, the State Council of Defense, and the State Railroad Commission.

Reorganization and Personnel. As a result of the removal of headquarters of the Chief of the Irrigation Division of the U. S. Department of Agriculture from Washington to Berkeley in April, 1918, immediate supervision of co-operative irrigation investigations in California has automatically reverted to Dr. Samuel Fortier, Chief of the Irrigation Division. The writer is, however, continued in immediate charge of co-operation with the College of Agriculture of the University of California and of certain further projects within the state in connection with the other co-operative agencies named; also with the aid of Miss Reid M. Venable, office assistant, in charge of all records and data gathered through the California work. Special irrigation studies conducted on the University Farm at Davis, heretofore a part of the general co-operation in California, are now, because of their purely agricultural character, entirely paid for from College of Agriculture funds and are therefore not considered strictly part of the co-operative work and hence not reported. Mr. C. E. Tait, Senior Irrigation Engineer, is continued in charge of special studies in southern California.

Irrigation and Increased War Production.

One of the major activities of our work during the past two seasons has been that concerned with the increase through irrigation of war food production. In these activities Professors S. H. Beckett and Frank J. Veihmeyer, of the irrigation investigations staff of the College of Agriculture, have taken an especially important part. The following indicates in a general way the nature and extent of the more important of these activities and what has been accomplished through them.

(1) On April 17, 1917, eleven days after the declaration of war, called a statewide conference at Berkeley to consider increasing the part of irrigation in war food production. This conference was attended by representatives of important community and commercial irrigation enterprises, by the Dean of the College of Agriculture of the University, and representatives of the following public agencies interested in or connected in an administrative way with California irrigation: State Department of Engineering, State Water Commission, State Railroad Commission, State Irrigation Board, Division of Rural Institutions of the College of Agriculture of the University of California, and California Co-operative Irrigation Investigations. Principal direct or indirected outcome: Decision No. 4278 of the State Railroad Commission removing legal restrictions on emergency deliveries of surplus irrigation water by utility water companies; emergency act (Act No. 1732K, 1917 legislature) drafted by the Water Commission and the Railroad Commission in conference with this office removing legal restrictions from emergency deliveries of irrigation water by individuals and mutual water companies.

PLATE XI.

Upper figure.—Lining canal with cement gun, Lindsay-Strathmore District.
Lower figure.—Booster plant, Terrabella Irrigation District.

PLATE XII.

Upper figure.—Trenching for pipe line, Paradise Irrigation District.
Lower figure.—Double pipe line from pump, Westside Irrigation District.

(2) With the concurrence of the State Engineer and the Attorney General an appeal was sent through the State Council of Defense to irrigation districts urging emergency irrigation deliveries, whenever possible, to landowners outside of districts.

(3) Held numerous conferences with the principals involved in a controversy preventing access to irrigation water by Byron-Bethany Irrigation Company (only partially successful), followed by plane-table topographical survey of 2500 acres within the project and special study and report on the most economical preparation for irrigation of the land involved.

(4) Instituted investigation resulting, after numerous conferences, in co-operation with State Council of Defense, in the signing of a stipulation practically vacating, for the period of the war and a reasonable time thereafter, an injunction issued in 1903 against the opening of Lake Land flood water canal from Kings River, capable of watering at least 30,000 acres. A total of 2000 acres was actually irrigated under this stipulation in 1917 and at this writing it is expected that a considerable larger acreage will be benefited next season. The Lake Land Canal and Irrigation Company built a new permanent concrete weir across Cross Creek, at a cost of about $9,000, to handle water under the stipulation, has spent about $6,000 additional in canal improvements, and will do further work at a cost of about $10,000 looking to readiness for 1919. The stipulation signed permits Lake Land Canal to divert water when the flow in Kings River exceeds 8000 cubic feet per second. As this figure is excessive, an effort is likely to be made by the parties interested to alter the stipulation to permit diversions at any time there is waste water.

(5) Co-operated with State Council of Defense in effort to hasten irrigation of lands in Solano County under an abandoned promotion enterprise. No important results to date.

(6) Co-operated with motor and irrigation machinery supply houses in San Francisco by which a ruling was obtained from the War Priorities Board through the Federal Food Administration for California permitting the obtaining of priority orders for motors, engines, and pumps needed for irrigation of essential crops.

(7) Instituted investigation (July to August, 1917) of controversy between people of Lake County and Yolo Water and Power Company involving use of water of Clear Lake for irrigation. This was the basis for an agreement obtained April, 1918, by the Federal Food Administration for California, working in conjunction with this office, by which 10,000 acres of rice, not otherwise possible of growth in 1918, have been irrigated with an estimated yield in excess of 300,000 bags containing 30,000,000 pounds of rice. Throughout the irrigation season this project has been under the general supervision of Professor S. H. Beckett, acting in this matter as a representative of the Food Administration.

(8) Held several conferences with farmers and officials in Anderson-Cottonwood Irrigation District with a view to aiding in hastening use of water made available by Anderson-Cottonwood Irrigation District Canal. A small demonstration project was undertaken at Redding.

(9) In co-operation with Division of Rural Institutions of the College of Agriculture made emergency survey of irrigation resources of California and their better utilization during the war. Briefly this indicated:

(*a*) A probable addition of 100,000 acres in 1917 to the normal annual increase in the irrigated area in California.

(*b*) That canals and principal laterals were already constructed to water an additional 500,000 acres, with construction due to be completed by 1920 that would make irrigation available to 300,000 acres more.

(*c*) That reorganisation and consolidation of existing irrigation enterprises, completion of irrigation works under way, efforts toward temporary or permanent adjustment of local irrigation controversies, and more complete and more careful utilisation of normal irrigation supplies have all been definitely stimulated by the war emergency.

(10) Made field survey of the possibility of increasing the area of irrigated wheat in California in both 1917 and 1918. The survey in 1917 indicated that a considerable opportunity existed in Imperial, San Joaquin and Sacramento valleys for increasing the irrigated wheat acreage of California as a war measure, but that owing to local attitude toward the irrigation of wheat, the largest increase in 1918 would likely be in San Joaquin Valley south of Fresno. The survey in 1918, made in August and September, showed less increase over 1917 than had been expected.

(11) Made a field investigation of opportunities for temporary utilization of water wasted into Auburn Ravine from power plant of Pacific Gas and Electric Company and gave publicity to findings.

(12) Investigated controversy regarding use of Clark Ditch in El Dorado County and aided in bringing water users and owner together.

(13) Made field investigation and assisted in settlement of controversy over distribution of irrigation water in Orangevale colony.

(14) Investigated grain suffering from drought under irrigation systems in Fresno, Tulare and Kings counties, and joined with Fresno County Food Administrator in enlisting co-operation of the Food Administration for California in obtaining consent of owners of alfalfa farms and orchards to give water for period of two weeks to save between 20,000 and 30,000 acres of wheat and barley. (Sudden high water in Kings River later reduced acuteness of this situation.)

(15) Made preliminary financial investigation of California irrigation, drainage and reclamation projects likely to undertake substantial expenditures during the war period. This investigation has been made to obtain information to assist in reporting on projects at the request of the Capital Issues Committee of the Twelfth Federal Reserve District. Subsequently, more complete reports were made on request of the Capital Issues Committee, through the Chief of the Irrigation Division, on fifteen of these enterprises in northern and central California.

(16) Acting for the Food Administration, made investigations of water shortage for rice under Sacramento Valley West Side Canal and recommended order, subsequently issued by the State Railroad Commission, placing supervision of water distribution under the entire system under a special representative of the Food Administration and the Railroad Commission for a ten-day period during the most acute shortage. Professor Frank J. Veihmeyer of our co-operative staff acted as such special representative, general supervision then being shifted to the County Food Administrator.

(17) Acting for the Food Administration, investigated a similar water shortage for rice in Oakdale Irrigation District and rearranged water deliveries to meet it.

(18) Acting in conjunction with the Power Administrator, secured the release of stored water for the irrigation of alfalfa and beans in Oakdale and South San Joaquin Irrigation districts.

(19) Acting for the Food Administration and in conjunction with Power Administrator, curtailed wasteful use of water in both Nevada City and Grass Valley, making the water thus saved available for food crops under the Excelsior Water and Mining Company's system in the Rough and Ready section of Nevada County; also acting for the Power Administrator, effected an economy in the use of water in mining in favor of the generation of hydroelectric power.

(20) Acting for the Power Administrator secured an agreement to conserve irrigation water in Browns Valley Irrigation District through rotating deliveries, the saving thus effected being available for power.

(21) Acting for the Food Administration and the Railroad Commission made adjustment of water deliveries in El Dorado County, under Western States and Diamond Ridge Ditch systems, to care for needs of essential food crops.

(22) Acting for the Food Administration and the Railroad Commission supervised the distribution of water under East Side Canal in Kern County during special emergency run of water provided to insure an additional crop of alfalfa on 2370 acres.

(23) Acting for the Food Administration investigated a proposed grain irrigation project under the Los Angeles aqueduct.

(24) Acting for the Food Administration investigated water shortage on Butte and Deer creeks, Butte County, and advised all users as to economies needed to save essential crops.

(25) Acting for Food Administration co-operated with the Railroad Commission and the Power Administrator in arranging for readjustments of water diversions from Feather River in Butte County by Sutter-Butte and Western Canal companies. This action was taken in connection with an acute water shortage in the rice fields irrigated from Sutter-Butte Canal and to furnish water needed to irrigate bean land prior to plantings.

(26) Rendered assistance to individuals and communities in laying out farm ditches and irrigation pipe lines, installing irrigation pumping plants, and preparing land for irrigation. This work was especially active during the early months of the war, twenty-five individual cases of this kind being handled during 1917, these covering a total of 2500 acres, and serving as centers of interest in the general food production campaign conducted by numerous public agencies.

(27) Investigated water shortage for rice irrigation west of the borrow pit of Reclamation District No. 108 in Yolo and Colusa counties due to scarcity of waste water from the irrigated areas about Colusa and north in Colusa and Glenn counties.

General Conclusions Regarding War Activities. Such work as we have been able to do in the interest of increased food production during the war period has indicated in a broad general way that large opportunities exist for co-ordination of effort and reduction of waste arising through nonuse or misuse of irrigation water. Due to the extreme water shortage during the past season in nearly every irrigation stream in the state, and to the disinterested activities of various public agencies, such as the Food Administration, the Railroad Commission and the State Council of Defense, there has, it is believed, been a more complete and more economical use of irrigation water than in any previous year. While in some cases individuals have patriotically suffered some monetary loss through the favoring of the more essential crops or through the temporary diversion of water from alfalfa or orchards to rice, beans, or some other annual crop at the moment requiring water if it were to be saved, such readjustments as have been made have not in general resulted in great hardship. In normal times those having a prior right to water and using it carefully can not be expected to give it up in favor of others merely because some crop more valuable for the minute can thereby be saved. But the experience of the year should be given emphasis as establishing an advance in the public point of view toward the right of individuals to waste irrigation water merely because the lower standards of earlier times, when many of the rights were acquired, sanctioned such waste. Especially do the cases of the pumping of water from Clear Lake for the irrigation of 10,000 acres of rice in Yolo County and of the virtual setting aside for the war period of the injunction against the diversion by Lake Land Canal of flood waters of Kings River, constitute a step forward, even if only for the period of the war. It is very doubtful if any substantial damage was done to anyone through the pumping from Clear Lake and it is certain no damage was done by the use of Kings River flood waters. These, however, are only the more striking instances of real conservation of irrigation waters through actual beneficial use that have been brought about through war necessity. The important question now is, when the war emergency has passed, can public sentiment be kept up to the point of holding to the principles found workable in 1918? In our judgment, a way should be found through appropriate legislation to continue in effect the substance of Emergency Decision No. 4278 of the Railroad Commission and Act No. 1732*k* of the 1917 legislature.

Co-operation With Farm Advisors.

The work done under this head has been a prominent feature of our activities during the past two seasons. As already indicated it has been chiefly with the farm advisers of Shasta, San Joaquin, El Dorado, Merced, Placer and Kern counties. In Placer, El Dorado, Merced and Kern counties the taking over of the existing irrigation systems by the landowners, through the organization of irrigation districts,

has been the question given attention. Investigations in El Dorado County are still under way by Professor F. J. Veihmeyer and in Kern County by A. L. Fellows, Senior Irrigation Engineer. A report advising the immediate formation of an irrigation district in Merced County with an initial area of 175,000 acres has been prepared in conjunction with the State Engineer and is now before the irrigation district committee of the Merced County Farm Bureau. In Placer County we are now co-operating with the Farm Bureau in the preparation of a general field map of the irrigated and irrigable lands under the irrigation system of the Pacific Gas and Electric Company, this map to aid in advising as to the feasibility of forming an irrigation district there.

Other important co-operation with farm bureaus has been as follows:

Shasta County. Advised as to diversion dams for small individual irrigation systems near Redding and as to use of drainage waters for irrigation in Fall River Valley. This work was done by Fred C. Scobey, senior irrigation engineer.

Yolo, Napa, Sonoma and San Joaquin Counties. General reconnaissance of irrigation conditions, advice and assistance to individual irrigators in laying out and preparing land for irrigation, irrigation experiments, irrigation practice, etc.

Monterey County. Investigation of opportunity for forming an irrigation district in Clark Colony.

Investigations of Use of Water from Kings River.

Incident to the pending organization of the Kings River Conservation District, the State Water Commission was called on early in 1918 to measure all diversions from Kings River during 1918. Our office has co-operated in these measurements through furnishing needed automatic water registers. It was obvious, however, that a thorough study of the use of this water measured by the Water Commission would be needed properly to interpret the records of diversions, and we have co-operated with the Water Commission in this by having an agent on the ground throughout the irrigation season. It was at first hoped that considerable data could be gathered as to the actual use of water in many individual cases. The territory, however, proved so large and the interests on the river so varied that it was soon found impossible to put much time on detail. It was realized that the ultimate irrigation efficiency is not likely to obtain on Kings River for many years but it is obvious that if the water is to be made to perform a fuller duty than at present, and the duty contemplated for the Pine Flat Project, many water economies will have to be inaugurated by the various diverting and distributing agencies along the river. With this thought in mind, Mr. Harry Barnes, the field agent on the work, endeavored to ascertain where leakages occur and what corrective measures are necessary to eliminate them. To this end consideration was given to the organization and administration of each company, the cost of water, methods of payment, and the general relations of companies and consumers. The general physical condition of canals and ditches of each system was noted, the mileage and acreage involved, and the system of maintenance followed. It was also necessary to ascertain the crops irrigated and the seasonal demands for water, methods of irrigation followed and the reasons therefor, effect and extent of subirrigation, and the general conditions as regards drainage. Finally, it was necessary to obtain some understanding of local water rights, intercompany agreements, and litigation. No plans have been made to publish Mr. Barnes' report of this work, it being intended mainly for an office record for public agencies interested.

Irrigation of Rice.

Investigations of rice irrigation have continued during the past two years, duty of water studies being in co-operation with the State Water Commission and experiments in irrigation practice being partly in co-operation with the Water Commission and partly in co-operation with the Bureau of Plant Industry of the Department of Agriculture at their Biggs station. Results of investigations in 1918 are not available at this writing. They have, however, included measurement on 8280 acres on four rice farms near Norman and Maxwell in Sacramento Valley, a

PLATE XIII.

Upper figure.—Bear River Canal below Lake Spalding, Placer County. Landowners are considering forming an irrigation district to control the distribution of this irrigation water.

Lower figure.—Crocker-Huffman Canal in the foothills of Merced County. The taking over of this system is under contemplation by the landowners around Merced through the formation of an irrigation district.

PLATE XIV.

Upper figure.—Typical irrigated truck garden, San Diego County.
Lower figure.—Multiple-arch dam, La Mesa Reservoir, near San Diego.

repetition for the fifth consecutive year of the Biggs experiments in time and method of applying water, and a duplication of these experiments on some of the so-called "goose" lands near Norman. Rice irrigation studies in 1918 have been carried on by Harlowe M. Stafford under the general supervision of Professor S. H. Beckett. Results of measurements of duty of water for rice in 1916 and of the experiments at Biggs in 1914, 1915, and 1916, together with a general description of methods of preparing and irrigation rice land in California, have been published as Bulletin 279 of the California Agricultural Experiment Station, by Ralph D. Robertson.

The area in rice in California in 1917 was approximately 80,000 acres and this increased in 1918 to over 100,000 acres. The measurements of water used show a definite increase in economy, the average depth of 7.25 feet applied on the fields under observation in 1916 having been reduced to an average depth of 5.5 feet on the twenty fields under observation in 1917.

No definite arrangements have yet been made regarding publication of results recorded since 1916, the time of further publications being dependent on the extent to which rice irrigation studies are to be continued beyond 1918.

Duty of Water Investigations, Yuba and Nevada Counties.

During the irrigation season of 1917 a study was made of the use of irrigation water under the system of the Excelsior Water and Mining Company in Yuba and Nevada counties, the expense being borne jointly by our office and the water company and consumers. The occasion for this study was a controversy between company and consumers as to a fair water rate to be charged by the company. A rate higher than had previously been in effect was granted by the Railroad Commission, March 19, 1914. Later a compromise rate of 10 cents per miner's inch-day for the seasons of 1915 and 1916 was allowed by the Commission under stipulation that company and consumers join in the expense of an engineer to make determinations of the water requirements of the section. The work covered ten fields, three in Pleasant Valley, four in Penn Valley, and three near Smartsville, and was done by J. B. Brown, representing this office. These fields were selected with a view to representing the different soil types, crops and topographic situations in the three representative areas. Mr. Brown's report, fully illustrated by maps, was mimeographed and furnished interested parties early in 1918. He found that under present practice a fair general duty is one miner's inch to 3.25 acres, or an average net duty of 2.5 acre-feet per acre, 80 per cent of the irrigated area being in meadow. General recommendations made by Mr. Brown called for substituting a 10-day rotation delivery to all irrigators for the varying rotation period found in effect, for insistence on adherence to the schedule adopted, and for the installation of standard weirs for measuring all deliveries.

A Demonstration Pumping Plant and Pipe Distribution System.

The wide use of underground water supplies for irrigation in California has led to a high type of pumping equipment in certain sections of the state and a distinct advance in practice is noticeable as compared with a decade ago. Unfortunately, however, pumping installations are most frequently made by local dealers in pumping machinery and possible economies are not always looked out for, especially where pumping for irrigation is relatively new. A similar situation exists with reference to underground pipe distribution systems. A demonstration project has been designed and its installation supervised by Milo R. Williams, Senior Irrigation Engineer, on the Herman E. Berg ranch three miles north of Yuba City, the owner furnishing all labor and material and this office all engineering. In addition to indicating a modern pumping installation for the development of underground water supplies and demonstrating the design, manufacture, and installation of an up-to-date concrete pipe distribution system for both orchards and field crops, the project, when fully completed, will include the careful laying out, levelling, and checking of land where necessary, in accordance with a thorough ground survey and good irrigation practice. A water supply of approximately 2000 gallons per minute was obtained from two 12-inch open-bottom wells 84 feet deep. These wells were individually

tested and the pumping equipment designed to meet the conditions found, this design calling for the placing of a direct connected horizontal pump 13 feet below ground water level and being made practicable through the building of a water-tight concrete pit midway between the two wells and connected with them through sealed-off tunnels. The concrete pipe for the distribution system was manufactured by the wet-tamp method in accordance with specifications prepared by Mr. Williams, a typical run of 12-inch pipe failing to break under a test of 40 pounds internal pressure, and the 20,000-foot installation developing only three leaks sufficient to show on the surface and require repairing.

Sewage Irrigation.

Studies of sewage irrigation in California, begun by Milo B. Williams, senior irrigation engineer, in 1916, have been continued. Topographic surveys, study of sewage requirements, and design of distributing systems were made by Mr. Williams for each of the cities of Ontario, San Luis Obispo, and Santa Rosa. The first two of these cities have made installations in accordance with the recommendations prepared in this office and are demonstrating the successful distribution and utilization of sewage waters through pipe distribution systems of modern design. A visit to the sewage farms of Ontario or San Luis Obispo is alone needed to show the desirability of better irrigation engineering in the laying out and operation of sewage farms than has heretofore obtained.

Concrete Pipe Investigations.

California leads all other states in the use of concrete pipe for irrigation purposes. There are approximately 150 independent manufacturers placing pipe on the market within the state. The demand from engineers, manufacturers, and farmers for data regarding the making and uses of concrete pipe and the lack of such knowledge led this office to start a project in March, 1917, covering a careful field study of the manufacture, classification of materials being used, testing of pipe made by different methods, and a study of concrete pipe design and their uses for irrigation purposes, this work being in charge of Milo B. Williams, senior Irrigation Engineer. The testing required the standardizing of testing methods and field equipment for the study of pipe resistance to internal pressure and other factors, such as imperviousness, which indicate the quality of structure. The project was continued for approximately six months, during which time a series of tests were run on 10-inch and 12-inch pipe. The results brought out a great range of quality and strength in concrete pipe being placed on the market. The manufacturers expressed a willingness to furnish pipe for extensive continuation of the work in order to obtain data for the purpose of standardization of the industry, which, in many instances, has suffered from serious failure of pipe construction. This project is to be continued at the conclusion of the war and the investigational work carried into the laboratory.

Co-operation with State Land Settlement Board.

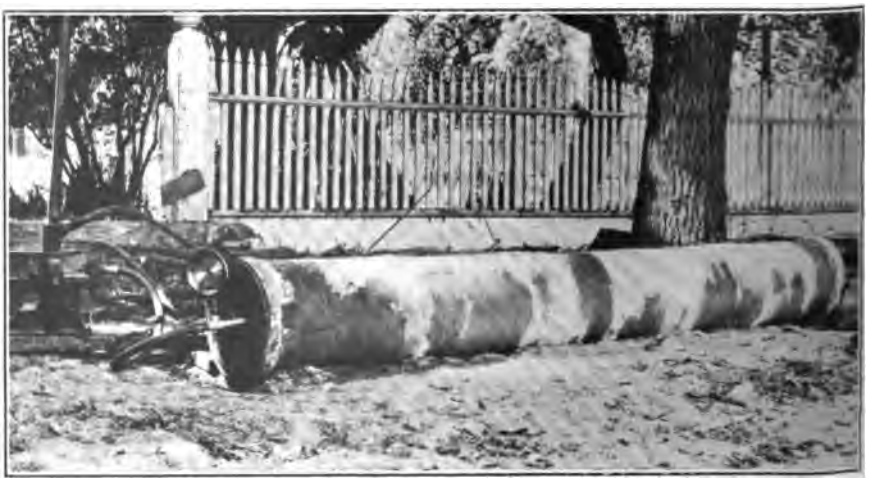
Our force has been called on from time to time for investigation of tracts under consideration for purchase by the State Land Settlement Board. Since the purchase by the board of the Durham Colony in Butte County, Milo B. Williams, senior irrigation engineer, has had personal charge of irrigation development on the tract and also of the construction of an adequate drainage system to remove surplus storm waters. In connection with development of the irrigation system, the financial co-operation of all ditch owners along Butte Creek was obtained in the construction of a permanent community diversion dam across Butte Creek. Other engineering work has consisted of the subdivision of the tract into farms and a topographical survey of the 4500 acres of irrigable land to a five-tenths foot contour interval. The contour survey is being used as a basis for irrigation and drainage design and an individual contour map is furnished each settler for use in the preparation of his land for water application. A contour key map is being made covering all subdivisions and the entire water system. All structures are being installed in concrete and concrete pipes will be used extensively for irrigation and drainage gates, checks.

PLATE XV.

Upper figure.—Rectangular measuring weir and automatic register, rice duty of water investigations, Yolo County.

Lower figure.—Measuring small streams with V-notch weir and automatic register, Yuba–Nevada Counties duty of water investigations.

PLATE XVI.



Upper figure.—Gate tower, Woodward Reservoir, South San Joaquin Irrigation District.
Lower figure.—"Sweating" string of 12-inch concrete pipe under five pounds pressure per square inch. This pipe, however, failed to break under 40 pounds pressure. Concrete pipe investigations.

culverts, etc. Pipe ranging in size from 10 inches to 36 inches in diameter is being made on the colony under specifications issued by this office.

Miscellaneous Investigations.

In addition to the emergency investigations reported under war activities, numerous miscellaneous studies have been made from time to time and individual advice and assistance given in connection with installation of individual irrigation pumping plants, design of distribution systems, surveys of individual or community reservoir sites, etc. One of the more important of the miscellaneous investigations has been one by Fred C. Scobey, senior irrigation engineer, dealing with supplemental irrigation systems for range stockmen to tide over periods of extreme drought like that experienced in 1918.

Special investigations made at the request of the State Engineer included investigations of proper duty of water and irrigability of lands in the proposed extension of Cardiff Irrigation District along the coastal plain of San Diego County; investigation of water supply and irrigability of numerous suggested sites for the Pacific Colony, authorized by the last legislature; investigation of proposed irrigation reservoir site and irrigability of adjacent lands in Placer and Nevada counties.

Special Investigations in Southern California.

Mr. C. E. Tait, senior irrigation engineer, in charge of special investigations in southern California, has submitted the following summary of work done under his immediate direction during the past biennium:

Special irrigation investigations in southern California have pertained mainly to two major subjects, the investigation of silt in Colorado River and the Imperial Valley canal system, and the utilization of Mojave River for irrigation. Much time, however, has been devoted to consultation and in preparing brief statements and reports, some of which required investigations in the field.

Silt Problem in Imperial Valley. The investigation of the silt problem in Imperial Valley was undertaken in the spring of 1917 and the field work will be completed by January 1, 1919. The purpose of this work has been to obtain data which should be useful in the construction, operation, and maintenance of irrigation works for silt-laden waters. Although most of the work has been done in Imperial Valley, the investigation has not been confined altogether to that section and tests are being made in Yuma and Palo Verde valleys as well as at different points on Colorado River. The silt problems are the most important and the most difficult confronting the water users of Imperial Valley. Every problem of any consequence as to the future of the irrigation system relates to the ability to properly handle the silt carried by Colorado River and deposited in the canals. The proper construction and design of works, the control of the river, the establishment of security for bonds, the operation and maintenance of the canal system, and the maintenance of proper soil conditions for agricultural production all depend on success in handling silt. Other canal systems in the southwest have similar problems and the results obtained in this work should have general application.

This investigation is in co-operation with Imperial Irrigation District and the expense has been about equally divided between the district on the one side and Co-operative Irrigation Investigations on the other side. The work has been done jointly according to an approved outline which provides for the interchange of all data now being obtained as well as data obtained by the parties to the co-operation prior to the present investigation. On the part of the district the work has been in charge of J. E. Peck of the engineering staff. The district appropriated $4755 to cover expenses and equip a laboratory at Calexico. In addition to this, the district has furnished an automobile and paid all running expenses for the use of its engineer and the agents of this division engaged in the work. This division made some additions to the laboratory equipment and furnished the greater part of the field apparatus such as water samplers, current meters and surveying instruments. The members of our force engaged on the work have been H. F. Blaney, H. M. Lukens, F. J. Veihmeyer and F. D. Bowlus.

Employees of the irrigation district assisted in the work by taking water samples at various points on the main canal. Arrangements were also made with the mutual water companies of Imperial Valley for the taking of daily samples on the distributing canals by their zanjeros.

The U. S. Reclamation Service has made available for use in this investigation the results of tests on the percentage of silt in Colorado River at Yuma conducted throughout a period of nine years. These determinations are useful for comparison and for showing the variation from season to season.

The most of the work has been under two main divisions of the subject, one being to determine how the silt and sand are being distributed throughout the Imperial canal system, and the other to determine the carrying capacity of silt and sand for different velocities of current.

In order to determine the distribution of the silt and sand throughout the canal system, samples were taken daily at 18 different stations on the canals for one year and the percentage of silt was determined on the weight basis from these samples by filtering and weighing. This part of the work is completed and the results are tabulated.

In connection with the studies of the carrying capacity of different velocities, many tests are being made on canals of different sizes, grades, and mean velocities, and at different seasons giving different percentages of silt in the water. These tests show the effect of depth and velocity on the transportation of silt and sand and they take account of size of particle and specific gravity. The samples are taken with a sampler especially devised for taking samples at any depth in the canal. This part of the work will be continued until the first of the year.

In addition to these main divisions of the work, samples have been taken from Colorado River at Topock, near Needles, twice monthly for one year. These samples are taken at different depths and in such manner that the results are comparable to those obtained by the Reclamation Service at Yuma.

Mojave River Investigations. The investigation of conditions on Mojave River was begun in January, 1917. About that time the Board of Supervisors of San Bernardino County was called upon to act on petitions of landowners and entrymen in Victor Valley for the formation of two irrigation districts, and, desiring more information on the conditions, our office was requested to join the State Department of Engineering and the county in a joint investigation. For this purpose the Mojave River Commission, consisting of W. F. McClure, State Engineer; J. A. Sourwine, County Surveyor and Engineer for San Bernardino County, and the writer, was appointed and $3000 was set aside by the county to be expended through the county's engineer in the joint investigation. About $2000 of this amount was used. The greater part of the field work was done during the first half of 1917 and a preliminary report was made to the Board of Supervisors in August, 1917. Since that time some additional field work has been done and a more complete and final report covering the entire investigation is now being printed as Bulletin No. 5 of the State Engineering Department. F. J. Veihmeyer and Fred D. Bowlus assisted materially in the field work. C. G. Haskell, who was conducting an investigation on wells throughout the West, co-operated with the commission on the work in Victor Valley and the data secured by Mr. Haskell was made available for the report on Mojave River.

CONSERVATION OF FLOOD WATERS IN COACHELLA VALLEY.

The last biennial report included a preliminary report prepared by this office on the Conservation and Control of Flood Waters in Coachella Valley (Bulletin 4, California State Department of Engineering). This report made recommendations for the spreading of the flood waters of Whitewater River over the debris fan below the canyon to benefit the underground water supply in Coachella Valley, and for the examination of two different routes for a flood water channel through the valley from Point Happy to Salton Sea.

One of these routes, that on the northeast side of the valley and known as Thousand Palms Canyon Wash, was believed from the data then at hand to be the better of the two possible routes, but the data did not justify final recommendations.

Other agencies who were advising the Coachella Valley Storm Water District, also the district's engineer, recommended the other route, that on the southwest side of the valley, and for a time there was much difference of opinion among the property owners as to the proper plan of works.

To bring about harmonious action, the question was referred to a board of three engineers having no previous connection with the matter. These engineers, after making preliminary surveys, made recommendations which agree with those of this office, both as to the spreading of water as a conservation measure, and as to the proper route for the flood water channel. They recommended one important additional feature to the proposed works in a regulating reservoir for the flood water, to be formed by the construction of a dam across the Whitewater channel at Point Happy.

The survey shows that a dam 40 feet high would impound 8400 acre-feet. With such a regulator, the flood water channel through the valley need have a capacity of only 3000 second-feet, instead of about 10,000 second-feet, that would otherwise be required.

The estimated cost of all the works is $300,000, of which amount $68,382 is for the dam and reservoir, $199,244 is for the flood water channel, $10,000 is for spreading flood waters, and the remainder is for contingencies. The district has voted a bond issue of $300,000 to carry out these plans. In accordance with the recommendations in Bulletin No. 4 the district applied to the government for the reservation of some of the public land along Whitewater Wash for use in water conservation work and such reservation was made.

Use of Water for Alfalfa in Imperial Valley. Field studies of the use of water for alfalfa in Imperial Valley by Frank J. Veihmeyer and the writer, begun in 1914, were completed in November, 1917, and a report is now being prepared. Six representative alfalfa fields were under observation and measurements were made on eight tracts on these fields. The least amount of water, a depth of 3.85 feet, was used on clay soil, while the dune sand soil received a depth of 6.53 feet. While the use of water is determined primarily by the soil type, the measurements show that the care used in preparation of the land for irrigation, the size of the "lands" or checks, and care in applying water greatly influence the annual requirements. It was found that the amount of silt carried onto the land also materially affected the amount of water required. In addition to the measurements of amounts of water applied the distribution of the moisture in the soil was determined and also measurements of the deposition of the silt carried in by irrigation water on different portions of the fields were made.

Miscellaneous Investigations. In addition to these two major subjects, brief reports were prepared as follows:

In July, 1918, a report was made at the request of the State Engineer on the water supply and water rights in San Jose Creek Valley, where the Pacific Colony had under consideration a site for the institution. In September following a supplemental report was made giving discharges and other data on pumping plants along the San Jose Creek as desired by the State Engineer. The field work in this connection was done by Mr. Bowlus.

In September, 1917, a report was made to the Federal Land Bank at Berkeley on the water supplies for the irrigation of lands of 16 applicants for loans in the southern part of Antelope Valley. In August, 1918, a general report on the underground waters of Antelope Valley, including all portions of the basin, was made to the Federal Land Bank.

In August, 1918, together with the State Engineer, a report was made on the power and irrigation project of the Volcan Land and Water Company in San Diego County, this being understood to be for the Capital Issues Committee.

In August, 1918, an opinion was prepared on the effect of waste water from flowing wells on the water supply in Orange County. This was for the County Farm Adviser and the Council of Defense.

In September, 1918, together with Mr. Bowlus, a report was prepared for the Capital Issues Committee on the power and irrigation project of the Sespe Light and Power Company in Ventura County.

In October, 1918, a report was prepared for the Capital Issues Committee on Imperial Water Company No. 3.

At the request of the board of directors of the Santa Ana Irrigation Company of Orange County, a preliminary examination has been made to recommend the type for headworks for the company's canal on Santa Ana River. As soon as time will permit, it is the intention to make a more thorough and broader examination as the matter involves a number of other considerations, including the possibility of a joint dam and headworks with the Anaheim Union Water Company and the protection from floods of the Orange County highway and railroad tracks which follow the banks of the river.

Irrigation District Legislation.

Probably no law on the statute books is more amended than the California Irrigation District Act. Members of our force have continued to give attention to the improvement of this law and in this connection have, when called on, worked with the California Irrigation Districts Association and with the irrigation committees of the legislature. There is obviously need for general revision of the California Irrigation District Act, but it has been our conclusion that this general revision should not be undertaken until the act becomes more fully worked out. This is because each succeeding legislature has before it numerous changes of more or less detail to meet particular situations that arise, and a general revision now would not be permanent. There has been a very noticeable tendency among some of the newer irrigation districts to ask for amendments that would make the formation and financing of district easier. Remembering the earlier history of California irrigation districts and the subsequent history in other western states, it has seemed prudent to members of our force in touch with the situation to be exceedingly cautious in moving in that direction. The older California irrigation districts have established themselves as sound financial investments and any reaction might be very injurious to worthy and sound district enterprises yet to be organized. It is our belief that our safe course is to impose suitable restrictions on doubtful projects but leave the way open and furnish every encouragement to enterprises economically and physically feasible.

In our judgment, the California Irrigation District Act should not permit the organization of irrigation districts where a majority of the substantial interests involved are unfavorable. Several districts of this type have been organized in California during the past few years, and although no bonds have been authorized by the Irrigation District Bond Commission, sufficient expenditures in some cases have been made and assessments levied therefor to create a considerable burden on some of the landowners. This could have been prevented if the Department of Engineering had been given authority to pass on preliminary financing and on the nature and extent of preliminary engineering investigations after organization, or, better still, if the Department of Engineering could have been provided with funds and itself have made these preliminary investigations, with power to veto the organization if found not to be practicable or feasible at this time.

It is believed that the time is coming, if it is not already here, when the crops being chiefly grown in irrigation districts must affect the maturity of the bonds to be issued. With this fact in mind, it is suggested that section 30*a* of the California irrigation district act be amended by adding proper maturity of the bonds to be voted to the matters on which the irrigation district bond commission shall state generally its conclusions when passing on proposed works.

In our judgment, one of the most progressive steps open in matters of irrigation district organization is the making of preliminary investigations of proposed districts at the expense of the state. The time to guide these enterprises, and to co-ordinate and consolidate the different points of view inevitably present, is when they are starting, and the interest of the state in not only holding back unwise ventures but above all in fostering desirable projects is paramount to all other interests. Worthy and feasible projects are held back through lack of state aid and advice at the early stages when most needed.

Much thought has been given in California and in other western states to the matter of state control of irrigation districts, and a larger measure of such control has been granted in California than in any of the other states. A change in sentiment

in this matter is plainly noticeable. Where a few years ago some of the older districts and some of the prominent engineers dealing with irrigation districts were opposed to any state control whatever, a well-defined desire for such control now exists. In other words, the state is coming to be recognized as the best friend the districts have, and sound thought has come to realize that without a substantial measure of state control, the beneficial participation of the state through the Department of Engineering or the College of Agriculture or the Irrigation District Bond Commission could not be supplied. In these days of active irrigation district organization in California, we believe no mistake can possibly be made by giving to the state an increasing responsibility and an increasing measure of engineering and financial control. Merely a limited measure of state control leads the public to a presumption of state approval, which is clearly much more undesirable than no state supervision whatever.

Land Settlement Problems; Federal and State Co-operation.

Since land settlement became a problem in California some five or six years ago, our force has been interested in and has given considerable attention to the question. Co-operation with the State Land Settlement Board has already been referred to. The broad land settlement program recently inaugurated by Secretary of the Interior Franklin K. Lane suggests future activities in California in which the Co-operative Irrigation Investigations are bound to be interested. The purchase and settlement in the state of farm lands in colony groups, as already begun by the State Land Settlement Board at its initial colony at Durham, is indicative of a larger program along similar lines quite sure to follow. The question arises, however, are there not worthy and desirable irrigation and reclamation projects in California where the settlement already accomplished makes the present state program, even if extended through the working out of Secretary Lane's program, insufficient to meet all of our needs? It is our belief that there are such projects in California and that under adequate limits on speculation at the expense of the ultimate purchaser of the lands, the use of the credit of both the state and the federal governments is both needed and justified in their financing. Past reclamation experience in this country is sufficient, even if it were needed, to prove that where the public credit is used in irrigation and land settlement projects, the ultimate settler must be protected against excessive land prices. In our judgment, the use of both state and federal credit, under proper restrictions and adequate control of construction and management, would be justified for such enterprises as Imperial Irrigation District, the pending conservation district at Fresno, the proposed irrigation districts on San Joaquin and Kern rivers, and the proposed Iron Canyon project in Sacramento Valley. Obviously, however, these are all too big and all already too far developed, either as dry land communities or as operating irrigation systems, to make possible the settlement of all of the land by the state or the nation. Furthermore, the settlement of such enterprises can only be accomplished after many years of relatively slow development. This makes the saving to the settler merely in the lower interest rate public credit would give a matter of great moment. Above all, however, the use of state credit would enable these larger projects to develop, even if only slowly, whereas without such state credit the construction of the storage works needed for full utilization will be difficult to finance. The problem is to develop a policy that will make such aid practicable and at the same time carry along with it a safe land settlement plan adapted to projects of varied ownership and interest and of too great size to form a single settlement group. This in itself will require adherence to the essential features of the land settlement policy being developed in California at the state colony at Durham and in a larger way being outlined under the leadership of Secretary Lane. Certainly in whatever plan is worked out a considerable measure of state participation is inevitable if the best interests of the state are to be realized. Certainly, also, the making of real opportunities on the land, where, with small initial payments, qualified settlers can earn the cost of their farms and their living out of the soil, will be a governing essential of the program. To follow any other course would be only to disregard completely the lessons past irrigation and reclamation experience has furnished.

CONFLICT OF INTERESTS.

Irrigation. Under the head of "River Work," mention was made of investigations that were made by the Department of Engineering to ascertain the quantity of water taken from the Sacramento River for irrigation. Attention is invited to the table accompanying that discussion, which gives a list of all pumping plants along the river between Tehama and Knights Landing, together with much detail concerning each plant.

From the data furnished by the table, it is deduced that the total pumping capacity of all of the plants is about 2600 cubic feet per second. The time of operation varied from a few hours for some plants to five or six months for others. During the summer of 1918, the quantity of water pumped by all of the plants aggregated 529,852 acre-feet, which was 58 per cent more than was pumped from the river in 1917. The increase was due almost wholly to the increase in area of lands devoted to rice culture.

During the time the greatest quantity of water was being withdrawn the flow in the river was measured at Colusa and found to be 2185 second-feet.

The acreage to which the 529,852 acre-feet of water were applied is not known. There are approximately 3,500,000 acres of land in the Sacramento Valley, plains and foothills, of which more than 2,500,000 acres can be considered irrigable.* At the time the above figures were published in 1912, it was estimated that about 169,000 acres in the valley and adjacent Sierra foothills were being irrigated. A large increase in the irrigated area has been made since those figures were compiled, but information as to the amount of land now under irrigation is not at hand. It is not believed, however, that more than 10 per cent of the land susceptible of irrigation is being supplied.

Gaging stations are maintained on the river and each of its principal tributaries where they enter the valley, and the records show that the average quantity of water flowing into the valley is about 27,000,000 acre-feet a year. The quantity, if it could all be applied, would cover the irrigable lands to a depth of more than ten feet, but unfortunately most of it comes in flood flows and must always go to waste, leaving but a trickling stream, comparatively, to supply the lands at the time they most need it.

It is quite apparent, then, that if the irrigated area shall be extended as in the past, unless the summer flow can be augmented in some way, only a very short time will elapse until the river flow will be entirely exhausted, and that with only a small part of the valley irrigated.

*Report of Conservation Commission, 1912.

Navigation. The Sacramento River is recognized by the United States government as being navigable to Red Bluff, 254 miles above its mouth, at certain seasons of the year, and to Chico Landing, 202 miles, at all seasons.

The control of the river for navigation is exercised by the War Department. For many years the government has maintained a working force on the river, whose efforts are directed toward maintaining a navigable depth of seven feet in the lower river, four feet between Sacramento City and Colusa, and three feet to Chico Landing.

The appropriations by the United States for maintaining navigable conditions on the river since 1875 have amounted to about $1,500,000, while the state has expended more than a million dollars for the same purpose.

As a result of the efforts of nation and state to provide navigable depths of water, steamers ply up and down the river regularly throughout the year. There are drawbridges across the river above Sacramento at Knights Landing, Meridian and Colusa, where records are kept of the number of times the draws are opened for the passage of vessels.

For the fiscal year ending December 31, 1916, the number of craft registered as passing these bridges was as follows:*

	Knights Landing	Meridian	Colusa
Steamboats	645	466	518
Gasoline boats	373	87	34
Barges	474	214	212
Dredges	18	8	4
Pile drivers	3	1	2
House boats	21		
Yachts		2	
Sailing vessels		2	

The above figures do not include vessels passing which did not require the draws to be opened.

Commerce on the Sacramento River increased from 477,292 tons in 1912 to 875,780 tons in 1916, nearly doubling in tonnage in five years. Above the city of Sacramento boats carried 146,720 tons in 1915 and 168,157 tons in 1916, an increase of 14½ per cent in one year. The figures for later years are not yet published, but undoubtedly they show a continuing increase of water-borne traffic.

At the time the river reached its lowest stage last summer, when only 2185 second-feet were registered, which condition was brought about by the withdrawal of water for irrigation, no complaints were made on that account by the navigation interests operating on the river, but the government was compelled to dredge channels across bars which

*Annual report, Chief of Engineers, U. S. Army, 1917.

had formed below the confluence of the American River, both above and below the city of Sacramento.

Notwithstanding that complaints have not yet been made against the irrigators, it is quite evident that if withdrawals of water from the river are to be increased every year, the time will soon come when there will not be sufficient water for the needs or navigation.

The Impending Conflict. The Department of Engineering has long seen the approaching conflict between the interests of agricultural production requiring water for irrigation, and the interests of navigation which must have the same water, or a part of it, upon which to transport the commerce of the valley.

Water is required to produce crops and water is useful to transport those crops to market at a figure that will leave a profit to the producer. The rates for transportation on the river are generally lower than by rail, unless in instances where the railroad charges have been reduced to meet the water rates.

The department has taken occasion to suggest that close study should be made with a view of determining just how irrigation can be developed to the fullest extent without destroying or impairing the great asset the valley possesses in its cheap means of transportation.

Department engineers have devoted considerable study to the subject, but as their time is well occupied with the routine of their respective duties, none have had the time to give it the intensive and extensive study the subject requires.

It is known that opportunities exist for storage of surplus waters by construction of reservoirs in the mountains. Some data has been accumulated from time to time, and it is believed that sites not yet examined can be found.

There is some doubt that enough storage capacity can be found which will enable the entire valley to be irrigated, but certainly if all available sites were utilized, it would enable a very great extension of irrigation to be made without impairing other interests.

In this connection, attention is invited to the Report on Pit River Basin, by the U. S. Reclamation Service in co-operation with the Department of Engineering, 1915, and the report on the Iron Canyon Project by the Reclamation Service, together with a report of a board of review, reviewing said report, 1914. The review referred to is published herewith as Appendix "B."

The survey of Pit River Basin discovered a site where a 90-foot dam would store 650,000 acre-feet of water. The Iron Canyon Project report shows the possibility of storing 650,000 acre-feet.

The consummation of both or of either project would go a long way toward ameliorating the conditions threatening.

But the construction of great reservoirs and the accessory works to utilize them is enormously expensive and can not be undertaken by private or small community enterprises.

It seems the time has arrived when thorough investigations should be made by the state to ascertain what assets it possesses capable of conserving its waters so necessary for the important industries depending upon them.

It is urged that the Department of Engineering, by reason of its organization and equipment, is the natural agency through which the required information should be obtained. Attention is invited, too, to the fact that a large part of the normal force of engineers employed by the department—experts in the matters named above—are away with the army. Soon after peace is secured, they will be returning, and their services will be available if funds and authority are given for their employment in this work.

Unless well directed effort shall be made, it is greatly feared that the conflict of interests above set forth will reach a point where loss and irreparable injury will result to all.

These matters are earnestly commended for consideration by the executive and legislative branches of the state government.

IRRIGATION DISTRICTS.

Following the enactment of the so-called Wright Act, within eight years 49 irrigation districts were created. Few or none had been carefully considered before being organized. Some had but little if any water available, and no knowledge of the requirements of irrigation or the cost of providing works.

As a consequence of the unfavorable conditions attending their birth, few reached adolescence. Indeed, only nine of the entire number are in operation today. Some of these, after many and long struggles, succeeded in effecting compromises with their creditors at figures ranging from 28 to 75 cents on the dollar of indebtedness, refunded their bonds, have secured their water, built the works and became prosperous.

One, Walnut District, never incurred debt and has had no trouble. Others have maintained existence but in a somnolent condition, and have not yet awakened. One, Happy Valley, issued no bonds, acquired no property, and was considered dead, but two years ago it was revived by an act of the legislature legalizing its organization, since which it has arranged to purchase a system, enlarge it to the district's needs, and has voted to issue $615,000 in bonds for its purposes and $280,000 of the bonds have been sold.

Bulletin No. 2 of this department was compiled by Mr. Frank Adams, Irrigation Manager, U. S. Department of Agriculture, and was published two years ago. It gives such a complete history of the rise and fall of the irrigation district movement that it is unnecessary to dwell upon it further here.

In 1897 the act was supplanted by the Bridgeford Act, under which, with its various amendments, the reorganization of the old districts was effected and under whose provision all recently organized districts have been formed.

In 1911 an act was passed providing that when bonds of a district were certified by the State Controller, they should be available for all the purposes that other municipal bonds are.

To obtain the certificate named the entire project has to be approved by the Superintendent of Banks, Attorney General and State Engineer. For convenience this body is called the Bond Commission. Since the Bond Commission was created, it has investigated the bond issues of a number of districts, most of which have been approved and the bonds certified.

The effect of the certification of irrigation district bonds has been that where, before this law was enacted, they were hardly salable at 75 to 80 per cent of par, the same bonds are now quoted as high as 108 and new issues frequently bring 97 or more at the first offering.

Since 1913 the law has required that the State Engineer shall investigate the project of all proposed irrigation districts. It also provides that in case the report shall be opposed to the formation of the district, if a second petition be presented signed by three-fourths of the property owners, the district shall be formed, notwithstanding the adverse report. Furthermore, if for any reason the State Engineer fails to file a report within the time specified, formerly one month but now ninety days, the district could be formed without the report.

Since this law became effective 35 examinations have been made. One petition was withdrawn upon recommendation of this office, two districts failed of election though favorably reported. Three petitions were disallowed upon adverse report, another was allowed though reported adversely. Two of the petitions disallowed were followed with petitions of three-fourths of the landowners and were organized despite the adverse reports. One was organized without a report, it being impossible to make a physical examination of the project in the time allowed.

In the case of the two petitions which prevailed against the adverse report, both of which are in the Mojave River drainage, the combined area was practically 100,000 acres. The available supply was manifestly insufficient to serve so much land and upon the recommendation

PLATE XVII.

Upper figure.—Hydraulic fill dam, floating pumping plant.
Lower figure.—Hydraulic fill dam, sluice delivering material.

PLATE XVIII.

Upper figure.—Hydraulic fill dam, distributing material.
Lower figure.—Hydraulic fill dam, settling the puddle core.

of this office a commission was created to investigate the whole matter and report just what might be effected in the use of the waters of Mojave River.

The report of the commission is published herewith as Appendix C, and will be issued as Bulletin No. 5 of this office.

Preparations are being made to organize several districts, some of which will be very large.

Since the act creating the Bond Commission became effective, this office has investigated for that commission 17 bond projects, for which the commission "validated" bonds aggregating $22,847,321. Some of the bond issues investigated were made before the act creating the commission was passed.

Some old bond issues still outstanding have never been submitted to the commission for validation. Several recent issues are now under investigation, but findings have not yet been issued.

Several of the districts organized in recent years are meritorious enterprises, but under present conditions have little hope of reaching the goal for which they were formed. The soil is fertile when watered, but in its arid condition is of very little value. The water for their development is available, but requires expensive works to utilize it. Without values to offer as security, bonds of such a district would not be salable excepting at ruinous rates of discount, and the Bond Commission is unable to see its way to authorize the issue of bonds, and unless governmental assistance can be given them, these districts must remain undeveloped.

It has been proposed that the state enter upon a colonization scheme to provide homes for returning soldiers. It is suggested that these districts might offer an opportunity for such exploitation by the state, since every landowner would gladly surrender a portion of his holdings at a nominal price for the sake of water to irrigate the remainder.

The following table gives a list of all irrigation districts now operating, with data concerning them:

Irrigation Districts in Operation November 1, 1918.

No.	Name of district	County	Year organized	Area, acres	Bonds voted	Address of secretary
1	Alpaugh	Tulare	1914	7,576	$280,000	Alpaugh
2	Alta	Tulare-Fresno	1888	130,000	543,000	Dinuba
3	Anderson-Cottonwood	Shasta	1914	32,500	1,055,000	Anderson
4	Baxter Creek	Lassen	1916	11,000		Lassen
5	Big Rock Creek[1]	Los Angeles	1890	30,000	253,000	Yermo
6	Blackrock	Inyo	1915	1,210		Big Pine
7	Browns Valley[2]	Yuba	1888	44,328	140,000	Browns Valley
8	Cardiff	San Diego	1916	700		Cardiff by the Sea
9	Carmichael	Sacramento	1915	3,113	90,000	R.F.D. 3, Sacramento
10	Fairoaks	Sacramento	1917	4,000	200,000	Fairoaks
11	Happy Valley[3]	Tehama	1891	18,300	615,000	Olinda
12	Honey Lake Valley	Lassen	1916	33,150		Amadee
13	Imperial	Imperial	1911	576,600	6,000,000	El Centro
14	Jacinto	Glenn	1918	19,660		Jacinto
15	La Mesa, Lemon Grove and and Spring Valley[4]	San Diego	1913	14,794	1,232,500	La Mesa
16	Lindsay-Strathmore	Tulare	1915	15,775	1,400,000	Lindsay
17	Little Rock Creek	Los Angeles	1892	3,000	60,000	Littl Rock
18	Long Vall y Creek	Lassen	1916	34,000		Doyle
19	Maxwell	Colusa	1918	8,000	270,000	Colusa
20	Modesto	Modesto	1887	81,183	2,215,021	Modesto
21	Mojave River	San Bernardino	1917	27,065		Victorville
22	Newport Heights	Riverside	1918	1,503		Santa Ana
23	Newport Mesa	Riverside	1918	670		Santa Ana
24	Oakdale	Stanislaus-San Joaquin	1909	74,146	2,399,500	Oakdale
25	Palmdale	Los Angeles	1918	4,000		Palmdale
26	Paradise	Butte	1916	11,200	350,000	Paradise
27	Princeton-Codora-Glenn	Glenn-Colusa	1917	18,200		Willows
28	Provident	Colusa-Glenn	1918	20,756		Willows
29	Redrock Creek	Lassen	1918	3,700		Ravendale
30	San Ysidro	San Diego	1911	485	25,000	San Ysidro
31	Scott Valley	Siskiyou	1917	5,340		Fort Scott
32	Southern Lassen	Lassen	1915	21,500		Doyle
33	South San Joaquin	San Joaquin	1909	71,050	3,835,000	Manteca
34	Stratford	Kings	1915	9,200		Stratford
35	Surprise Valley	Modoc	1918	17,500		Fort Bidwell
36	Terra Bella	Tulare	1915	12,000	1,000,000	Terra Bella
37	Tulare[5]	Tulare	1889	30,360	500,000	Tulare
38	Turlock	Stanislaus-Merced	1887	175,566	2,572,800	Turlock
39	Tranquillity	Fresno	1917	11,300		Tranquillity
40	Victor Valley	San Bernardino	1917	71,517		
41	Walnut[6]	Los Angeles	1893	869		Walnut
42	Waterford	Stanislaus	1914	14,434	465,000	Waterford
43	Webster	Madera	1915	15,000		
44	Westside	San Joaquin	1915	11,760	410,000	Tracy
	Total acreage			1,798,881		
	Total bonded indebtedness[7]				$25,910,821	

[1]Big Rock Creek District was dormant for many years; revived in 1914.
[2]Browns Valley District paid off its bonds at 30 cents on the dollar.
[3]Happy Vall y District revived in 1917. Only $280,000 of its bonds, required for present needs, have been validated.
[4]This district's bonds have never been validated.
[5]Tulare District bought up its bonds at 53 cents and burned them in 1903.
[6]Walnut District is the only one of the early organizations which has not had trouble. It never issued bonds.
[7]Less $640,000, Browns Valley and Tulare districts bonds paid and cancel d.

PLATE XIX.

Alpine Dam, Marin Municipal Water District.

PLATE XX.

Upper figure.—Alpine Dam, showing intake of siphon spillway.
Lower figure.—Downstream, showing outlet of siphon spillway.

MISCELLANEOUS.

STATE SUPERVISION OF DAMS. In former reports of this department, attention was called to the growing number of high dams being constructed for industrial purposes without supervision by public authority, and urged that proper safeguards to life and property should be provided by requiring all such structures to be submitted to state control as to plans and safe construction.

In response to the suggestions made for provision to place all dams under state inspection and supervision, the legislature enacted an amendment to the act creating the Department of Engineering, containing the following provision:

> It shall be the duty of the state department of engineering to pass upon all plans, specifications and estimates for the construction of dams now already constructed, in process of construction, or proposed to be constructed for the impounding of water other than the dams now coming under the authority of the California Railroad Commission. (Chapter 394, statutes 1915.)

The intent of the above quoted law is plain, but it is submitted that it confers little authority upon the Department of Engineering. "To pass upon plans" is not sufficient without authority to alter the plans if they are defective and to enforce compliance in construction with approved plans and specifications, or if structure is already constructed and found to be unsafe the state's agent should be clothed with power to compel the adoption of measures to make it safe.

The legislature in 1917 enacted a provision covering the subject, in chapter 377 (statutes 1917), as follows:

> SEC. 2. (*a*) All dams in the state of California, other than those for impounding mining debris constructed under the authority of the California debris commission, or dams constructed by a municipal corporation maintaining a department of engineering, shall be under the authority of the state department of engineering, and the department shall exercise supervision over any dam, the failure of which would endanger life or property, and shall have power to prescribe and enforce compliance with measures for making such dams safe against failure; *provided,* that this section shall not apply to any dam which is part of a "water system" as defined in section two of the public utilities act of this state, and nothing in this act shall be construed to limit the jurisdiction of the railroad commission over such dams.
>
> (*b*) It shall be unlawful for any person, firm, corporation or district to construct, maintain or operate any dam known to be unsafe, or which if the destruction or failure thereof would endanger life or property; or to construct, reconstruct, repair or improve, maintain or operate any dam which is or would be ten feet or more in height or which will impound water or other fluid to the amount of three million gallons unless the plans, specifica-

tions and construction thereof shall have been approved in writing by the state department of engineering.

(*c*) Any person, firm, corporation or district who shall violate the provisions of this section is subject to a penalty of not less than five hundred nor more than two thousand dollars for each and every offense. Each day that such violation of the provisions of this section shall continue shall be deemed and considered a separate and distinct offense.

(*d*) Any person acting for himself as owner, or as director, officer, agent or employee of any firm, corporation or district engaged in the construction, reconstruction, improvement or repair of any dam, the plans and specifications of which have been approved by the department of engineering, or any contractor, or agent or employee of such contractor, who shall knowingly permit work to be executed thereon contrary to the plans and specifications approved as aforesaid, or any inspector or employee of the department of engineering who shall have knowledge of such work being done and fail to immediately notify the department of engineering thereof, is guilty of a felony and subject to the penalty of confinement in the state penitentiary for not less than one nor more than five years.

(*e*) Upon the complaint of the department of engineering any district attorney is hereby authorized and directed to prosecute violations of the provisions of this section.

It will be observed that those dams constructed by mining interests under the jurisdiction of the United States Debris Commission, public utilities under the State Railroad Commission and municipalities having an organized engineering department are exempt from the jurisdiction of the Department of Engineering. Since that law became effective, July 15, 1917, the department has approved the plans and inspected the work upon the following dams, construction of which has been commenced or completed:

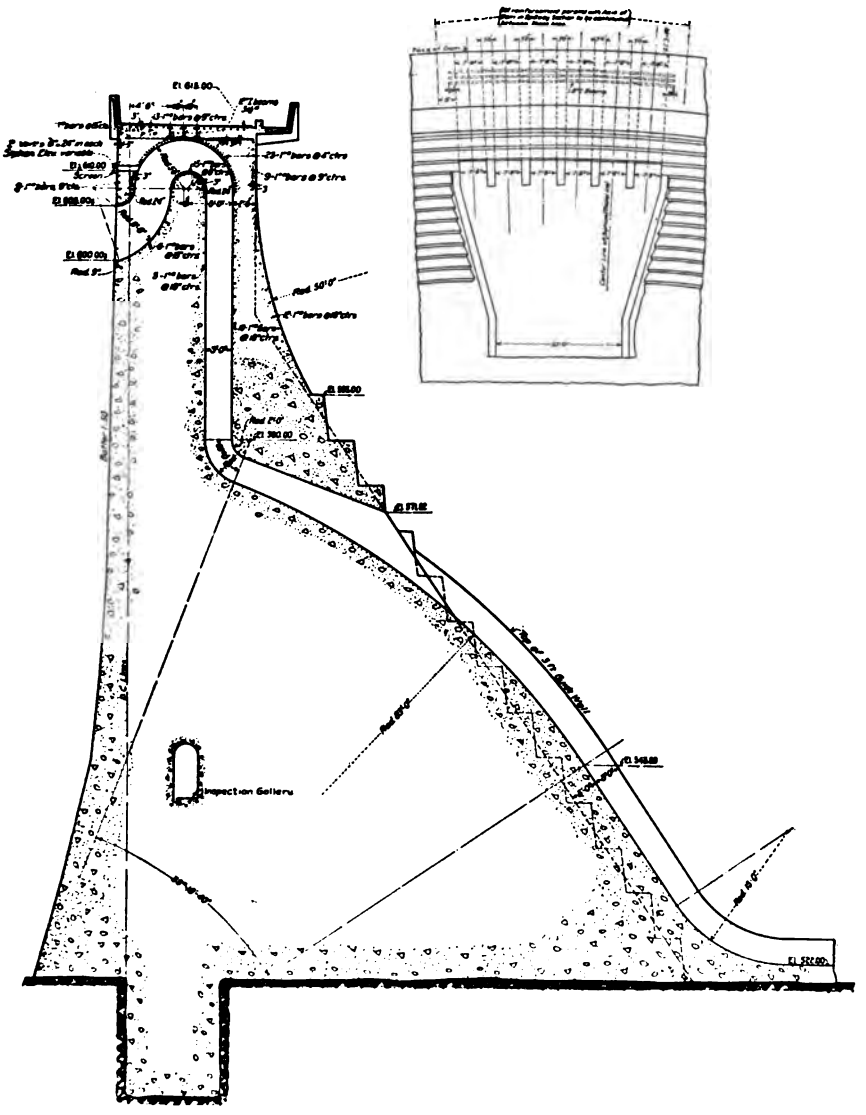
Woodward Dam.

Stanislaus County, eight miles north of Oakdale.
Owner: South San Joaquin Irrigation District.
Purpose: Storage for irrigation.
Type: Hydraulic earth fill.
Dimensions: Height 58 feet, base, maximum 300 feet, crown, 20 feet, length 3100 feet; storage capacity 49,000 acre-feet.
Source of water, diversion by canal from Stanislaus River.
Construction, completed May, 1918, cost $600,000.
Remarks: There are fifteen dikes or small dams across low places in the rim of the reservoir.

Paradise Dam.

Butte County, one mile from Magalia.
Owner: Paradise Irrigation District.
Purpose: Storage for irrigation.
Type: Hydraulic earth fill.
Dimensions: Height, 100 feet, base, maximum 325 feet, crown, 20 feet, length, 1000 feet; storage capacity, 2545 acre-feet.
Source of supply: Little Butte Creek.
Construction completed April, 1918.

PLATE XXI.



Alpine Dam, section, siphon spillway.

PLATE XXII.

Concrete pipe and trestle, Marin Municipal Water District.

Lake Hodges Dam.

San Dieguito River, San Diego County, 25 miles north of San Diego.
Owner: San Dieguito Mutual Water Company.
Purpose: Storage for irrigation, domestic and municipal use.
Type: Multiple arch, concrete.
Dimensions: Height, 130 feet, base, maximum 155 feet, crown, 16 feet, length, 750 feet, including spillway at side; storage capacity, 37,000 acre-feet.
Source of supply: San Dieguito River.
Under construction, will be completed about December, 1918.

Alpine Dam.

Lagunitas Creek, Marin County, 8 or 10 miles northwest of San Rafael.
Owner: Marin Municipal Water District.
Purpose: Storage for municipal supply of several towns.
Type: Gravity, cyclopean concrete.
Dimensions: Height, 100 feet, ultimately to be 170 feet.
Capacity, 3180 and 19,550 acre-feet, respectively.
Source of supply: Lagunitas Creek.
Construction under way.

Dorris Reservoir.

Modoc County, 2½ miles east of Alturas.
Owner: Dorris Brothers (W. J. and J. Dorris).
Purpose: Irrigation.
Type: Earth.
Dimensions: Height, 21 feet, base, maximum 123½ feet, crown, 30 feet, length, 3000 feet.
Capacity: 6640 acre-feet.
Source of supply: Diversion ditch from Pine Creek.
Construction under way.

Little Rock Creek.

Los Angeles County, 8 miles from Palmdale.
Owner: Little Rock Creek and Palmdale Irrigation Districts.
Purpose: Storage for irrigation and domestic use.
Type: Concrete multiple arch.
Dimensions: Height, 200 feet, length 440 feet, base, 233 feet, crest, 16 feet.
Capacity: 7460 acre-feet.
Source of supply: Little Rock Creek.
Construction not commenced.

The plans for several other dams have been submitted, but not yet passed upon.

BRIDGES. The law imposes upon the State Engineer the duty of passing upon the plans of all bridges to be erected over navigable waters of the state, and to prescribe the width of draw and of water channel.

The department in every instance acts in conjunction with the engineers of the War Department who have jurisdiction over navigable waters, and declines to approve any structure that is not satisfactory to them.

During the biennium just closing the department has considered plans for bridges as follows:

Sacramento-Solano.

Joint highway bridge over Sacramento River, near Rio Vista. Approved.
Type of bridge: Swing span, six truss spans and pile trestle approaches.
Width of draw: 226 feet.
Width of waterway: 2433 feet.
Length over-all: 2433 feet.
Remarks: Under construction, nearly completed.

Sacramento County Highway.

Bridge over Sacramento River, near Isleton. Considered.
Type: Bascule, truss span approaches.
Width of opening: 225 feet.
Width of waterway: 625 feet.
Length over-all: 1706 feet.
Remarks: Under consideration by the War Department.

Princeton—Colusa-Glenn Counties.

Highway bridge over Sacramento River at Princeton.
Type: Bascule.
Width of opening: 226 feet.
Width of waterway: 2 truss spans, 210 feet each, trestle, 470 feet, total 906 feet.
Remarks: Not commenced.

Feather River.

Nicholas—Sutter County Highway Bridge.
Type: Swing.
Width of opening: 100 feet each side of pivot pier.
Width of waterway: 3 truss spans, 525 trestle, 941 feet, total 1666 feet.
Length over-all: 1706 feet.
Remarks: Under construction.

Mad River Slough.

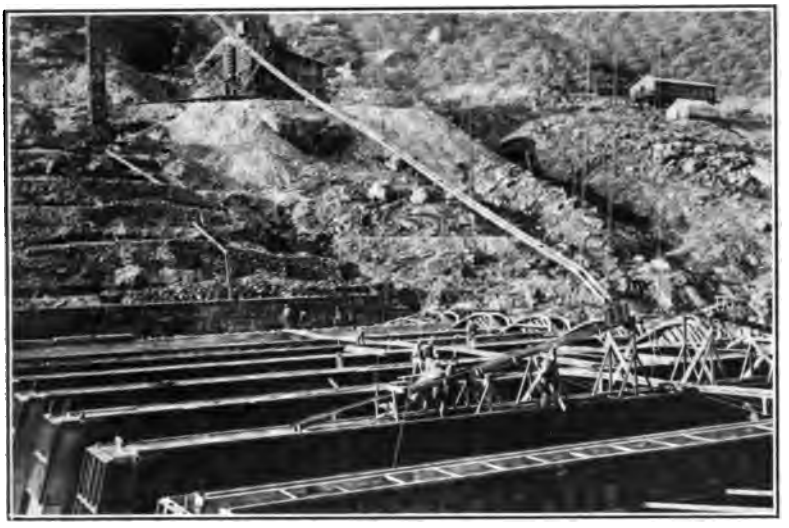
Humboldt County highway bridge.
Type: Single leaf bascule.
Width of opening: 38 feet.
Width of waterway: 232 feet.
Length over-all: 250 feet.

Cutoff Slough and Salt Slough.

Humboldt County private causeway.
Type: Earth embankment.
Width of opening: None.
Width of waterway: None.

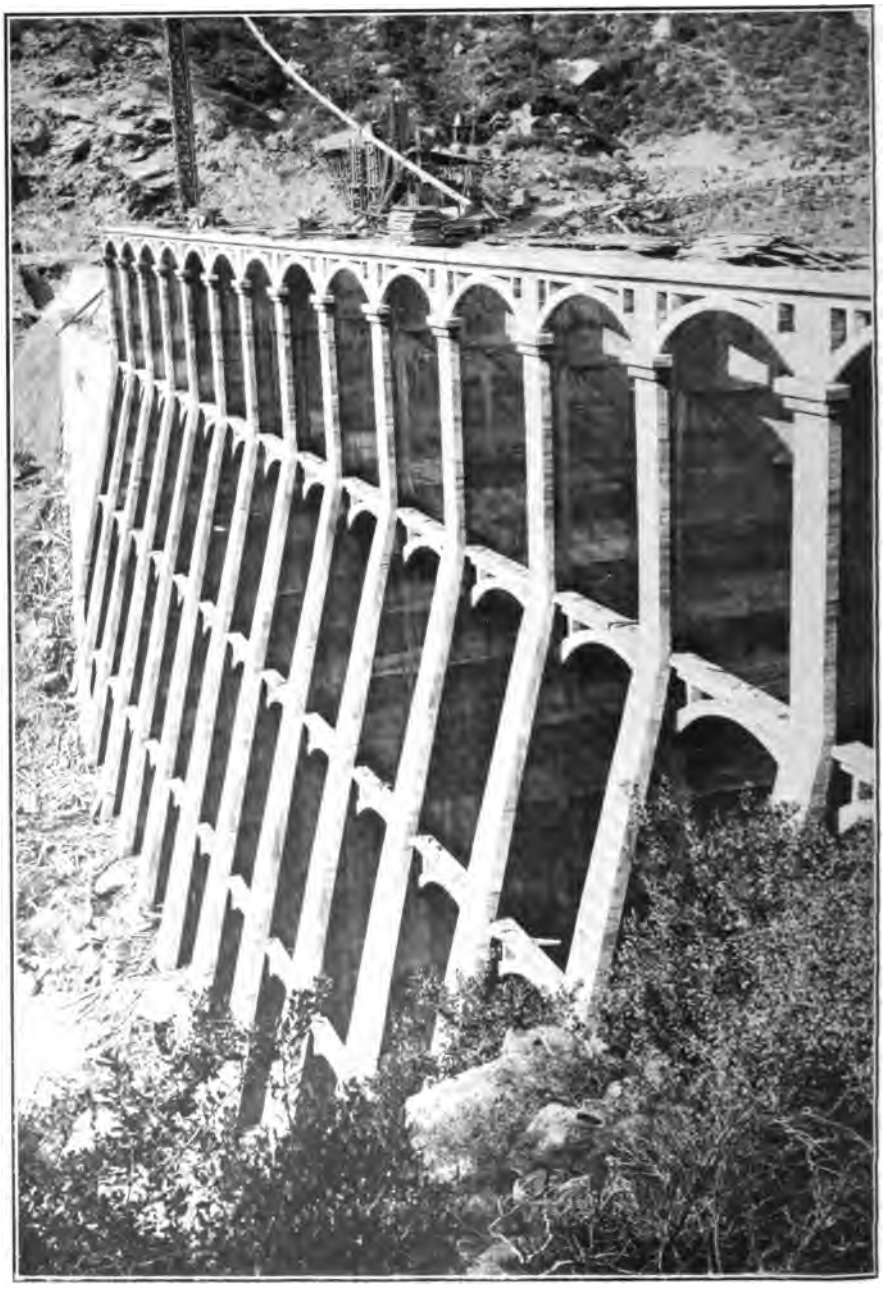
Remarks: These sloughs are blind channels in the delta lands of Eel River. They lie wholly within the property of one large estate, and are not used for navigation purposes, but fall within the definition of navigable streams of the statute, "all streams capable of floating logs, etc." The owners of the lands through which they pass petitioned the War Department for permission to construct a causeway by means of an earth fill across both channels, in *lieu* of drawbridges. The engineer corps of the War Department, considering that, as the channels are not in fact navigable, the United States did not have jurisdiction, referred the matter to this office. An investigation was made and the above recited facts ascertained, but as the department could not set aside a definition of law, declined to act. It is understood that the petitioners have since constructed the dams which will probably be allowed to remain until some one makes a showing of injury to navigation.

PLATE XXIII.



Upper figure.—Multiple-arch dam, concrete pier foundations, Lake Hodges Reservoir.
Lower figure.—Same in construction, September 21, 1918.

PLATE XXIV.



Lake Hodges Dam, San Dieguito River, October 19, 1918.

SAN FRANCISCO HARBOR FRONT.

The harbor front of the city of San Francisco is state property and is administered by a Board of State Harbor Commissioners, which has jurisdiction over the construction, operation and maintenance of the docks, wharves, buildings and appurtenanecs of every kind. The board reports directly to the Governor.

All engineering, including design and construction, is by law placed in the Department of Engineering, and is exercised through a chief engineer of the Board of Harbor Commissioners appointed by the department.

Mr. Frank G. White was appointed chief engineer July 7, 1916. His report covering the two years ending June 30, 1918, appears hereinafter in full.

It will be noted that the work of improvement, extension and additions to the wharf piers, sheds, and other equipment of the harbor has progressed steadily, despite the depression of the times.

To meet war necessities, the Belt Railroad was extended from the Transport Docks at Laguna street to the Presidio, and connected with a system of yard tracks constructed by the War Department for the handling of war materials. The extension was completed and connections made within two months after war was declared. A two-story building was erected at the foot of Jones street for the use of the U. S. Customs, Coast Guard and Quarantine Service. Also a building containing offices, waiting room, freight room, etc., was erected on Pier 14, for the accommodation of the U. S. Naval Training Station on Yerba Buena Island.

An item of the report which is not likely to attract much attention from the casual reader and yet is of more than passing interest, is the reference to Pier 42, the condition of which shows the need for using good materials and of employing efficient inspection in public works. The piles supporting the pier were encased with concrete as a protection from marine borers. The report says that "the concrete protection had disintegrated and washed out, leaving the piles exposed." The piles were eaten off by the *terredo,* and with the concrete debris, had fallen to the bottom of the bay. Complete reconstruction was necessary.

In this connection it is desired to call attention to the fact that this pier was constructed in 1906, before the Department of Engineering was created and the harbor work entrusted to engineers selected by it. In an early report of the department that method of construction as used in piers constructed under former regimes was discussed and it was stated that "in the depositing of the concrete around the piles there was little, if any, cementing power between the sacks of concrete."

No such work has ever been permitted since the Department of Engineering took charge of public construction.

Reference is briefly made to freight handling machinery to be installed in the sheds of Pier 3. This is a step in the right direction and one that it is hoped will be followed by many more of the same kind. To the public the most conspicuous improvements made or being made is the rebuilding of the sheds on Pier 46, which was destroyed by fire in 1915, and the construction of an overhead viaduct from the Ferry Building across the Embarcadero.

Chief Engineer White's report here follows:

REPORT OF CHIEF ENGINEER SAN FRANCISCO STATE HARBOR COMMISSION.

By FRANK G. WHITE, Chief Engineer.

I beg to submit herewith for your consideration my report as Chief Engineer of the Board of State Harbor Commissioners, for the two fiscal years beginning July 1, 1916, and ending June 30, 1918.

At the time of the presentation of the last biennial report on July 1, 1916, by my predecessor, Mr. Jerome Newman, there were under construction the following structures:

Pier No. 29, which was 68 per cent completed.

Repairs and additions to Pier No. 7, which were 85 per cent completed.

Repairs and additions to Pier No. 11, which were 50 per cent completed.

Repairs and additions to Pier No. 44, which were 5 per cent completed.

Addition to Pier No. 38, which was 2 per cent completed.

This work was all described in the last report and the structures have all been completed and placed in service.

For the purposes of this report, the work of the engineering department will be divided as follows:

1. Construction, piers, wharves, etc.
2. Maintenance and repairs.
3. Belt Railroad.
4. Buildings.
5. Paving.
6. Electrical.
7. Dredging.
8. Testing.
9. Designing and drafting.
10. General.

1. Construction, Piers, Wharves, etc.

Pier 3. This pier was constructed on the site of old Pier No. 3 and was designed for the use of river boats plying between San Francisco and points on the Sacramento and San Joaquin rivers. It is 138 feet in width and 706 feet in length and is constructed of reinforced concrete throughout. The supports are reinforced concrete piles which average from 90 to 100 feet in length. There is a depressed track on the north side and seven adjustable cargo aprons are provided to facilitate trucking between the boats and the pier. On these aprons the transportation company which will occupy the pier is installing motor driven chain conveyors to expedite the trucking at low stages of the tide. The fender line is the ordinary type with creosoted piles and untreated sheathing and the pavement is bituminous concrete in the driveway and sheet asphalt in the cargo areas.

In conjunction with the pier a section of reinforced concrete bulkhead wharf 423 feet in length and 45 feet in width was constructed as well as a passenger landing pier 76 feet by 99 feet.

The contract for the construction of the pier shed included a bulkhead wharf building and a waiting room on the passenger landing pier. The main pier shed is 699 feet in length and 112 feet in width with a passenger gallery extending along one side for about one-half its length. The bulkhead building is 398 feet in length by 30 feet in width and two stories high. In it will be located ticket and freight offices as well as the general business offices of the transportation company, baggage room, commissary, carpenter shop, etc. The waiting room on the passenger pier is 68 feet by 88 feet.

The buildings are all timber frame structures and the walls for a height of four feet are reinforced concrete. The remainder of the front wall of the bulkhead building is of metal lath and plaster on wood sheathing. On the rest of the buildings the walls above the reinforced concrete portion are two-inch solid mortar walls built up with a cement gun on ribbed metal lath.

Pier 3 was completed in March, 1918, and the pier shed, bulkhead building and passenger building were 40 per cent completed on June 30, 1918.

Pier 31. This pier is 150 feet in width and 800 feet in length. The type of construction is similar to that of Pier 29 adjoining it, the inner 590 feet being supported on reinforced concrete piles and the outer 210 feet on concrete cylinders which in turn have a foundation of timber piles. The deck is of reinforced concrete and the fender line and pavement are the same as on Pier 3. There is a flush track on one side and a depressed track on the other.

In conjunction with the pier there were constructed a section of bulkhead wharf 256 feet in length and 45 feet in width, and a wharf 150 feet in width and 245 feet in length connecting Piers 29 and 31. The bulkhead wharf and connecting wharf are also of reinforced concrete construction on concrete piles.

The plans for the pier shed include a building over the connecting wharf and bulkhead wharf. The latter building extends across the front of Pier 29 and has a length facing the Embarcadero of 610 feet. The buildings are timber frame structures and the walls are all of reinforced concrete excepting the frontwall of the bulkhead building which is cement plaster on metal lath.

Pier 31 was 97 per cent completed on June 30, 1918. The contract for the buildings has been let but their construction has not yet been begun. It is expected that they will be completed about December 1, 1918.

Pier 33. This pier is 803 feet in length and 150 feet in width. Except for the fact that the entire structure is built on concrete piles, the construction is the same as Pier 31, with the same track arrangement, fender line and paving.

The contract for Pier 33 included the construction of a section of reinforced concrete bulkhead wharf 45 feet in width and 440 feet in length. This connects the sections which were built in conjunction with Piers 31 and 35 and completes the permanent bulkhead wharf from the north side of Pier 27 at Lombard street to the north side of Pier 41 at Powell street. Pier 33 was 87 per cent completed on June 30, 1918.

Pier 46. On June 4, 1916, Pier 46, which was completed about the last of September, 1914, was destroyed by fire. Portions of the deck along the north side of the pier were uninjured and the majority of the creosoted piles were in good condition below high tide but the shed and the greater part of the deck structure were entirely destroyed. There was considerable discussion as to whether the pier should be rebuilt of timber or whether it should be removed and replaced with a reinforced concrete structure. It was finally decided to rebuild the timber structure and this was done by cutting off the burned portions of the piles, subcapping with creosoted timbers and building up to the deck level with short posts braced in both directions. The deck planking was covered with a bituminous pavement and a different type of shed was designed which, while of timber, would be more fire-resisting. A bulkhead building covered with metal lath and plaster was also planned so as to harmonize with the front under construction on Pier 44. The pier construction was started by Harbor Commission forces but later contracts were let for the different parts of the work. The pier was completed in November, 1917, the pier shed in December, 1917, and the bulkhead building in February, 1918.

Islais Street Wharf. The construction of this wharf was the initial step in the development of the Islais Creek-India Basin district. It covers the full width of Islais street along the south side of the Islais Creek Channel and extends from Third street west to Selby street. It is 1646 feet in length and 80 feet in width except for a distance of 180 feet from Third street, which is 66 feet in width. It is a creosoted pile timber structure covered with a bituminous pavement and has a railroad track extending its entire length. The Islais street wharf was completed in January, 1918.

Pier 42—Reconstruction. This pier was constructed in 1906, the supports being untreated piles protected by concrete deposited inside wood stave cylinder forms. Examinations by divers showed that in many cases the piles were in bad condition due to the fact that the concrete protection had disintegrated and washed out, leaving the piles exposed. In fact, in some cases the piles had been eaten through and with the protecting concrete, had fallen to the bottom of the bay. It was decided to remove all of the protected piles and replace them with creosoted piles. At the same time the shed and deck were rebuilt and the latter was covered with a bituminous pavement. The railroad track along the north side of the pier was also connected with the Belt Railroad which now does the switching. The contract also included a section of reinforced concrete bulkhead wharf 46 feet in width and 539 feet in length and a bulkhead building at the inner end of the pier shed. The reconstruction of Pier 42 was completed in June, 1918.

Pier 40—Addition. An addition about 19 feet in width was constructed along the north side of Pier 40. This addition carries a depressed railway track and was constructed on account of the congestion incident to the operation of the flush track in the center of the pier. It is constructed of timber on creosoted piles and has the typical creosoted pile fender line. The addition to Pier 40 was completed in August, 1917.

Pier 43—Addition. An addition 52 feet in width and 200 feet in length was constructed on the outer end of Pier 43. It is a creosoted pile timber structure and carries two railroad tracks. The addition was completed in February, 1917.

Bulkhead Wharf—Pier 9. A section of bulkhead wharf 45 feet in width and 233 feet in length was constructed at the inner end of Pier 9. It connects the sections previously built adjacent to Piers 7 and 11 and completes the permanent bulkhead wharf from the south side of Pier 7 to the south side of Pier 19. It is the typical reinforced concrete bulkhead wharf construction on concrete piles. The work was completed in August, 1917.

Breakwater—Fishermen's Lagoon. In order to furnish a safe harbor for the growing fleet of fishing boats, a breakwater was constructed along the Embarcadero from Jones street to Hyde street with a wingwall extending back along Hyde street to Jefferson street. The area within the breakwater was then dredged to the required depth. From time to time the wharves will be constructed inside of this lagoon for the use of the fishing boats. The breakwater was completed in May, 1917.

Wharf Between Jones and Hyde Streets. The existing wharf on the Embarcadero between Jones and Leavenworth streets was enlarged and extended toward Hyde street and is now used for handling lumber. The old portion which was 411.5 feet in length and 60 feet in width was widened to 120 feet and an extension 180 feet in length and 120 feet in width was constructed on the west end. The wharf is of creosoted pile and timber construction and was built by Harbor Commission forces. The work was completed in June, 1918.

2. Maintenance and Repairs.

Coincident with the large increase in the harbor facilities and in the tonnage handled, the work of maintaining the property under the jurisdiction of the board has also very largely increased. An efficient maintenance and repair department has been constantly at work and all structures have been kept in good operating condition. During the last year, it has been necessary to begin making extensive repairs to the untreated timber sheathing on the suspended fenders and the creosoted pile fenders. This was to have been expected and experience has proven that these

PLATE XXV.

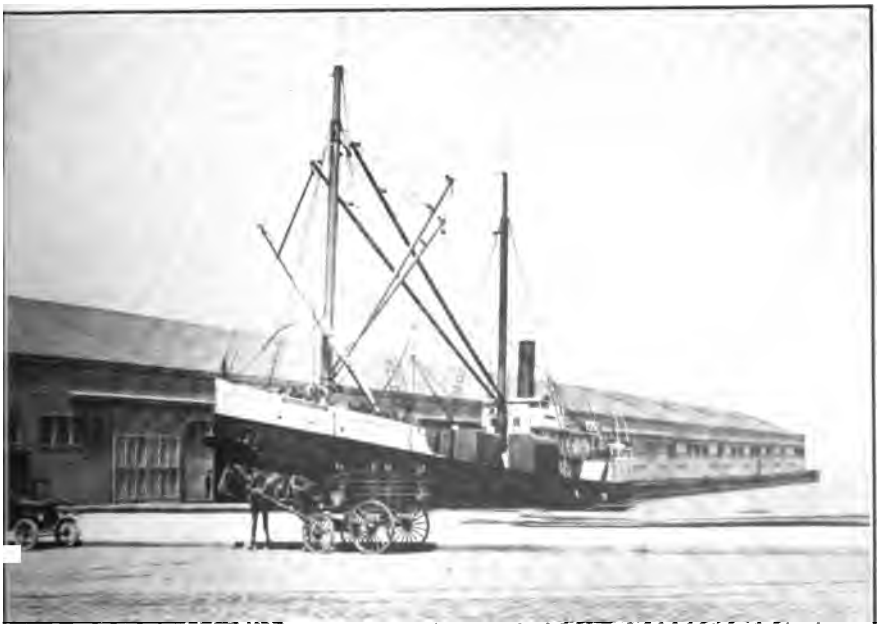
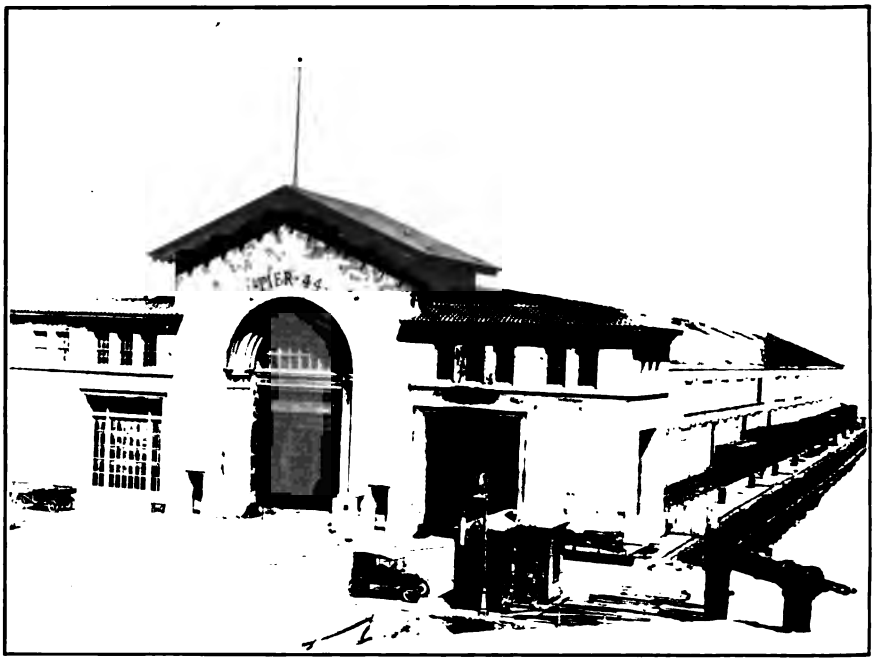
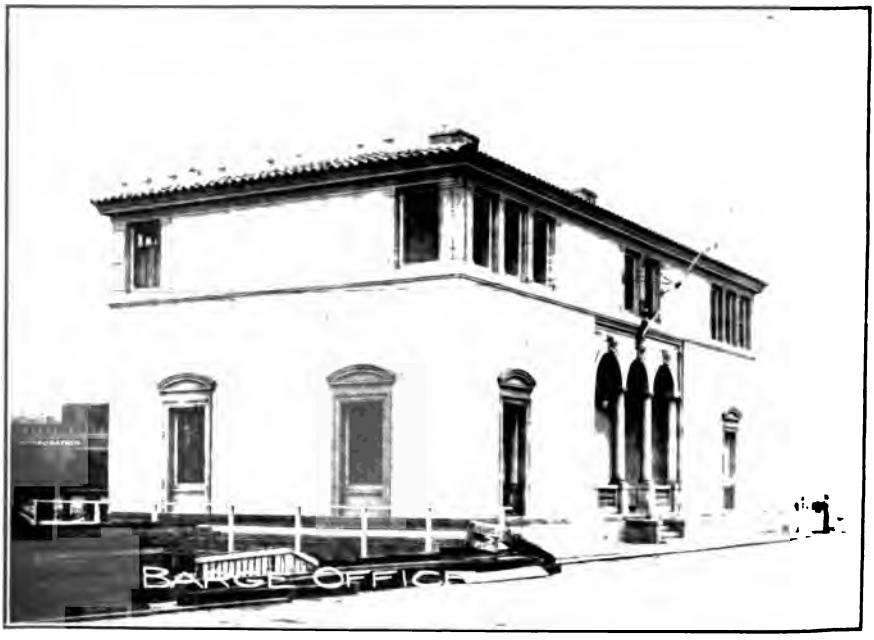


PLATE XXVI.





Upper figure.—Pier No. 44, San Francisco Harbor.
Lower figure.—Barge office.

types of fenders are much more economical to maintain than the old type of green pile fenders.

While most of the work was done by the maintenance and repair department, some of the larger jobs were done by contract. Of these the most important was the raising of the bulkhead wharf, between Howard and Harrison streets. On account of the nature if the subgrade upon which the sea wall in this locality was constructed, it settled, carrying with it the bulkhead wharf and bulkhead buildings. The greatest settlement occurred at the foot of Folsom street and amounted to about four feet. The work of raising the bulkhead wharf extended over a distance of 1150 feet. The concrete piles were cut off below the deck, the entire deck structure was jacked up to grade and the piles and bulkhead wall were built up to the necessary height to take the bearing. The work was carried out without interrupting the use of the structure above and was completed in April, 1917.

3. Belt Railroad.

The regular maintenance work of the Belt Railroad has been kept up and numerous private industry tracks have been constructed by the track-laying force. Several additional yard tracks were also built and the track laying on new piers was done by our own force.

Shortly after the declaration of war in April, 1917, the board was requested by the War Department to extend the Belt Railroad from the Transport Docks at Laguna street to the Presidio. This the board ordered done and the work was laid out so as to co-ordinate with the plans of the city for the construction of the Marina boulevard. The track was extended to the Presidio line and connected to the yards and sidings which were constructed by the War Department. The connection was made in June, 1917.

4. Buildings.

Contrary to the previous policy of the department and in order to expedite the work of construction it was decided to let separate contracts for pier and pier shed construction. This was first done in the case of Pier 29 and the same course was pursued with Piers 3, 31, 33 and 46, the buildings on which have already been described.

Pier 29—Shed. This building is a combination timber and steel frame structure with concrete walls, steel rolling doors and a corrugated iron roof. As constructed, it is 160 feet in width and 762 feet in length. As has been stated, the bulkhead building will be constructed in conjunction with the shed on Pier 31 and the adjacent connecting wharf. The shed on Pier 29 was completed in July, 1917.

Pier 41—Shed. Pier 41 was constructed in 1914 without a shed and was used for handling bulk cargoes, especially lumber. The need for covered cargo space, however, became so pressing that it was decided to construct a shed on this pier. The building is a timber frame structure with two-inch redwood siding and a roof of two-inch by four-inch redwood laid on edge, the construction being identical with that of the shed on Pier 46. The shed as constructed is 160 feet in width by 870 feet in length. Later it is the intention to extend the shed to the inner end of the pier and to construct a bulkhead building across the front. The shed on Pier 41 was completed in May, 1918.

Barge Office. A building to be used as waterfront offices and quarters by the U. S. Customs, Coast Guard and Quarantine Service was constructed on the Embarcadero near the foot of Jones street. It is a two-story building 33 feet by 67 feet. The foundation is reinforced concrete piles and the building is a timber frame structure, the outside being covered with metal lath and plaster. The Barge Office was completed in December, 1917.

Pier 36—Addition to Shed. The existing shed on Pier 36 was extended inshore to the waterfront line, the addition being 98 feet in width and 140 feet in length. The building is a timber frame structure with a four-inch redwood roof. The walls are of reinforced concrete for a height of about four feet and for the remainder of the height they are two-inch solid plastered walls on ribbed metal lath. The addition to the shed on Pier 36 was completed in October, 1917.

Wells-Fargo Building Addition. To care for the growing express business of Wells-Fargo and Company, an addition was constructed at the east of the building on Pier 14. The addition is irregular in shape but is approximately 100 feet in width by 270 feet in length. A portion covering an area 61 feet by 82 feet is two stories in height and the rest of the building is one story. It is a timber structure throughout. The addition to the Wells-Fargo Building was completed in May, 1918.

Naval Training Station Building. A building for the use of the U. S. Naval Training Station at Goat Island was constructed near the outer end of Pier 14. It is a one-story building 21 feet by 60 feet and contains a waiting room, offices, freight room, etc. The building is a timber frame structure covered with metal lath and plaster. It was completed in March, 1917.

Viaduct. Contracts have been let for the construction of a viaduct extending from the second floor of the Ferry Building across the Embarcadero to the west side of the street. It will leave the building about 50 feet north of the center and will land on the sidewalk on the west side of the Embarcadero near the north side of Market street. The viaduct will have a total length of 293 feet with four spans and a sidewalk width of 13 feet. It is expected that it will be completed about the first of December, 1918.

5. Paving.

The regular maintenance work on the pavement on the Embarcadero has been kept up and on account of the settlement of new fills, several areas of considerable extent were repaired by our street repair force. In addition, considerable work was done by contract, both on the Embarcadero and on other streets under the jurisdiction of the board.

Bay Street to Powell Street. This was the first section which was paved in accordance with the policy adopted by the board of providing a strip of bituminous pavement along the Embarcadero. It consisted of a strip of bituminous concrete pavement on a 6-inch concrete base 30 feet in width and 1935 feet in length. The work also included the construction of a cement sidewalk 20 feet in width, setting granite curb, the relaying of a portion of the basalt block pavement adjacent to the new work, and the construction of the necessary catch basins and drains.

Pacific Street to Union Street. This consisted of a strip of bituminous concrete pavement on a 6-inch concrete base, 40 feet in width and 1455 feet in length. The contract also included a granite curb for a portion of the distance, repairing with basalt blocks adjacent to the new pavement and the construction of drains and catch basins.

Folsom Street to Harrison Street. Following the completion of the work of raising the bulkhead wharf and bulkhead wall in this vicinity, a portion of the width of the Embarcadero was paved with basalt blocks. After the new fill on which this pavement was laid has settled sufficiently under traffic, the blocks will be removed and replaced by bituminous concrete.

King Street, Second Street to the Embarcadero. The existing pavement along this block was removed and replaced by a basalt block pavement on a 6-inch concrete base.

Folsom Street, Steuart Street to the Embarcadero. This block was paved with basalt blocks on sand. The contract also included the construction of granite curb, drains and catch basins.

The Marina, Laguna Street to Buchanan Street. The construction by the city of the first section of the Marina Boulevard necessitated the paving of the Belt Railroad track in this block. The work consisted of Topeka pavement on a 6-inch concrete base.

All of the above-mentioned work has been completed and is in service.

Washington Street to Market Street, and Howard Street to Folsom Street. These two sections of the Embarcadero are to be paved with bituminous concrete on a concrete base. The contracts have been let and the work is expected to be completed in September, 1918.

6. Electrical.

As in the past, all maintenance work and also all electric installations along the waterfront have been handled by our own electrical department. The work of extending the underground conduit system and the street lighting system has been carried on progressively and both are now complete from Channel street to Mason street.

As fast as new buildings have been constructed or existing buildings reconstructed, they have been permanently wired and high efficiency nitrogen lamps have been installed. This work has been done on Piers 7, 11, 15, 29, 41, 36, 42, 44 and 46 and in the Barge Office, Naval Training Station Building and Wells-Fargo Building addition. Piers 42 and 46 have also been wired for ship lighting and for furnishing power for cargo conveyors.

To assist in policing and patrolling, flood lights and projectors have been installed at advantageous points so as to light the sides and ends of the piers. These lights have been placed at Piers 41, 39, 37, 35, 26, 30, 32, 34, 42 and 46.

The efficiency of the electrical department in safeguarding the water front against disastrous fires has been increased by the appointment of an experienced fire marshal and by the installation of fire fighting apparatus. Eleven fire monitors have been placed on the roof of the Ferry Building and adjoining buildings, and 4000 feet of 2½-inch hose has been provided and mounted on thirty hose racks located in different parts of the building.

High pressure fire mains have been installed on Piers 35 and 37 with 1000 feet of 1½-inch hose mounted on ten hose racks on each pier, and each system is provided with connections for the city fire engines and fire boats as well as being permanently connected with the Spring Valley Water Company's water mains. Contracts have been let and work is proceeding on the installation of similar systems on Piers 3, 29, 31, 33 and 46.

Each pier is equipped with a 40-gallon portable chemical tank and the system of fire alarm boxes is being extended as is required.

The fire marshal makes periodical inspections of all fire equipment and also of all structures with a view to eliminating all fire hazards as far as possible. The hose is taken down and tested at intervals in order to be sure that it is always in first-class condition.

7. Dredging.

The regular dredging has been carried on as usual and the necessary depth of water has been maintained in all slips. In addition, extensive dredging operations have been necessary in the slips adjacent to the piers which have been recently constructed. The new fishermen's lagoon has been dredged so as to provide sufficient depth of water for the steam fishing tugs.

Dredging has been begun along the southerly portion of China Basin and large quantities of rock have been removed and used for straightening out and building up the seawall. This has accomplished the double purpose of securing the necessary depth of water and obviating the necessity of purchasing seawall rock.

The dredging plant has been maintained in a good state of efficiency and the department has been complimented by the inspectors of the Industrial Accident Commission on account of the good condition of the dredgers.

8. Testing.

The testing laboratory has proven indispensable in the carrying out of the extensive construction program of the last two years. All construction materials such as cement, structural and reinforcing steel, asphalt, roofing materials, paints, oils, etc., have been tested and analyzed and screen analyses have been made of sand, gravel and crushed rock for use in concrete. Samples of the concrete used in all construction work have been taken regularly and tested.

The testing for the State Department of Engineering has been carried on as in the past. All of the cement which the Department has used has been tested in our laboratory and in addition many tests have been made of concrete samples and of all sorts of building materials.

9. Designing and Drafting.

In addition to the plans for work which has been completed or which is under construction and which has been previously mentioned, the following plans have been prepared and are ready for placing under contract:

Extension to Pier 21; 108 feet in width and 200 feet in length, creosoted pile and timber construction.

Extension to Pier 22; 125 feet in width and 200 feet in length, creosoted pile and timber construction.

Bulkhead Wharf Adjacent to Pier 27; 45 feet in width and 64 feet in length, reinforced concrete construction.

Bulkhead Wharf at China Basin, extending from the entrance to Channel street to Pier 54; reinforced concrete structure 47 feet in width and 2145 feet in length.

Fish Packing House and Market at the Foot of Taylor Street; 47 feet in width by 100 feet in length, two stories in height, reinforced concrete construction.

Extension to Post Office; an addition to the second floor, 34 feet in width by 109 feet in length, structural steel, brick and concrete construction.

The following plans are well under way and will be completed in the near future:

Shed on Pier 33 and adjacent bulkhead wharf.

Extension of the existing shed on Pier 41, and shed on the adjacent bulkhead wharf.

Pier 1 to replace the existing pier at the foot of Washington street.

Permanent bulkhead wharves to replace the existing wharves in front of Pier 19 and from Pier 21 to Pier 27.

Plans for the improvement of Fishermen's Lagoon by the construction of a new free market, fish stalls, wharfinger's office, boat shops, boat ways, oil stations, net tanning house, and wharves, and wharf sheds for the wholesale fishing companies.

General plans for the development of the China Basin section and the India Basin-Islais Creek section of the waterfront.

10. General.

The unsettled conditions in all quarters due to the war have made construction programs difficult of fulfillment and it has been impossible in most cases to carry out previously arranged schedules. The shortage and inefficiency of labor and the difficulty of securing materials have increased steadily during the last two years and the cost of construction work has correspondingly increased. For these reasons it will probably be necessary to postpone the construction of part of the improvements mentioned above for which plans have been or are being prepared and to construct at the present time only such as are urgently needed.

On August 28, 1917, pursuant to your instructions, I left San Francisco for an inspection trip to the principal ports of the United States and Canada. I visited the most important ports on the Pacific and Atlantic coasts as well as on the Great Lakes and the Gulf of Mexico. I also attended the annual conventions of the Pacific Coast Association of Port Authorities at Portland, Oregon, and of the American Association of Port Authorities at Cleveland, Ohio. The entire trip covered a period of seven weeks and was outlined in a report to your honorable board, prepared after my return.

In February, 1918, I went to Seattle to investigate and report concerning the importation and handling of Oriental vegetable oils. The results of my investigations and recommendations as to the policy to be pursued in San Francisco were reported on March 5, 1918.

In conclusion, I desire to acknowledge the co-operation and efficient services of all employees of the Engineering Department.

San Francisco, Cal., July 1, 1918.

CANALS AND CANALIZATION.

The subject of navigation of inland waterways has engaged the attention of the people of California for a long time. In fact the first legislature, convened before the state was admitted to the Union, created a commission to study the subject.

The paralysis of rail transportation by the demands of war necessities has emphasized the need of supplementing the railways by other modes of transport.

Good highways are destined to play an important role in the development of the country, but for all that the waterways are capable of assisting in no small degree. Indeed, there are large areas of the most productive land in the state that by physical conditions are precluded from conveying their products to market in any other way than in boats.

Some years ago the legislature directed the Department of Engineering to investigate the subject of improving the rivers by canalization and constructing canals throughout the valleys of the state.

Without funds the department has been unable to make surveys, but whenever opportunity offered in the prosecution of other duties studies have been made on the subject.

In the last report of the department it was stated that:

> It is engineeringly feasible to construct tidal canals capable of conveying ocean-going ships to Sacramento and Stockton, at a comparatively low cost.
>
> It is engineeringly feasible to extend those canals several miles farther into the interior, with locks.
>
> Ships can be conveyed by canal within a few miles of San Jose.
>
> It is no greater engineering problem to build a lock-canal for ships from the sea to the heart of the city of Los Angeles than it was to build the great Manchester Canal.
>
> It would be no greater an engineering feat to build a barge canal from Red Bluff to Bakersfield than is the one now nearly accomplished of constructing the New York Barge Canal from Albany to Buffalo to accommodate barges carrying two thousand tons—the same distance and same elevations to overcome.
>
> Investigations have not gone far enough to show what the costs of construction or of operation of such canals would be.
>
> That all or any of the above are industrially feasible is not the province of this department to say, but it is urged that the question of cheap transportation is of such great importance to all that it should engage the earnest attention of the legislature to the end that an intensive study be made of the whole subject.

Following the suggestions contained in the above quotation, the Chamber of Commerce of Sacramento provided funds and requested the department to specially prosecute its studies on the feasibility of constructing a ship canal from Sacramento, connecting with deep water in the bay of San Francisco.

A survey was made under the direction of the department which developed the entire feasibility from an engineering standpoint of such a canal. Unfortunately, just as the surveys were being completed, the calls of war made it necessary to release nearly the entire force engaged on the survey, and the remaining members of the department have been physically unable to devote enough time from their routine duties to prepare the data for a report to the city of Sacramento. It is hoped, however, this may soon be done.

Attention is invited to the discussion in another chapter* of a threatened conflict between navigation and irrigation, and to the need of intensive study of the claims of both with a view to adopting measures for the preservation of both. With the close of the war and the return of the "boys" of the department who are with the colors, if funds are available, the department can vigorously prosecute the research needed.

SNOW STUDIES.

In previous reports of the Department of Engineering, the desirability of being able to forecast the probable magnitude of floods and the duration of run-off for all streams furnishing water for use, has been discussed. The department, in co-operation with agencies of the federal government, is measuring the quantity of water flowing in the streams at all times, and conducting research into the uses of water. It is known now with a fair degree of accuracy the average quantity of water discharged by the principal streams of the state every year, as well as the maximum volume of flood waters that are likely to be produced at any one time.

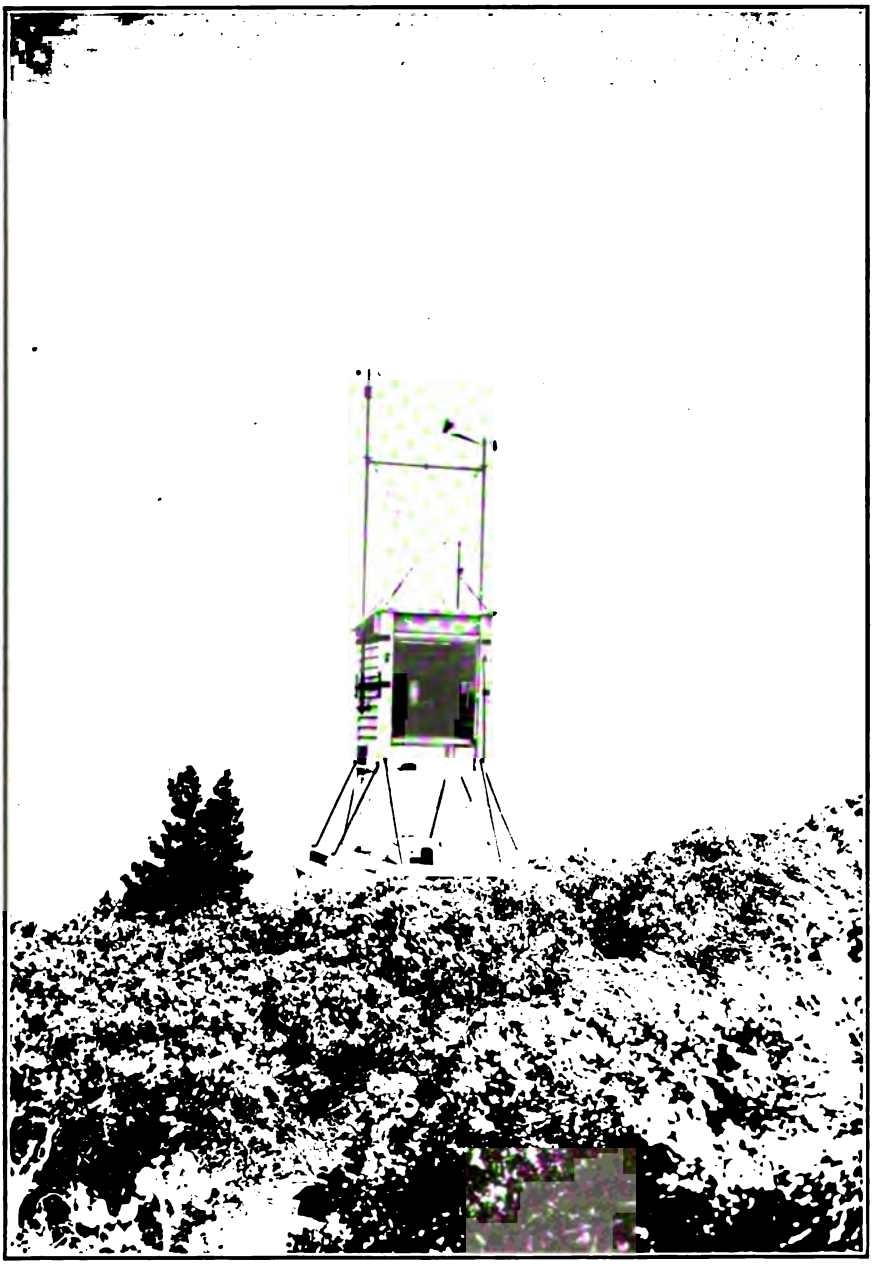
It is contemplated that ultimately reservoirs will be built in the mountains to retain a portion of the floods, so as to reduce the quantity to be cared for by the flood-control works in the valleys. This same water will then be used for irrigation and other purposes.

But it will be necessary to know beforehand when to begin filling the reservoirs. If they should be filled with early flow of water before it has reached flood stage, and then a flood came, there will be no place to store any of it. On the other hand, if they are held empty until flood danger is past, there may not then be enough to supply the needs of irrigators and other users.

Every artificial reservoir is accurately measured and gages show every day the quantity of water they contain, but nothing is known of the quantity back of them which is yet to come. The source of all floods and of the major part of the late-season flow is the vast snow fields about the heads of the streams.

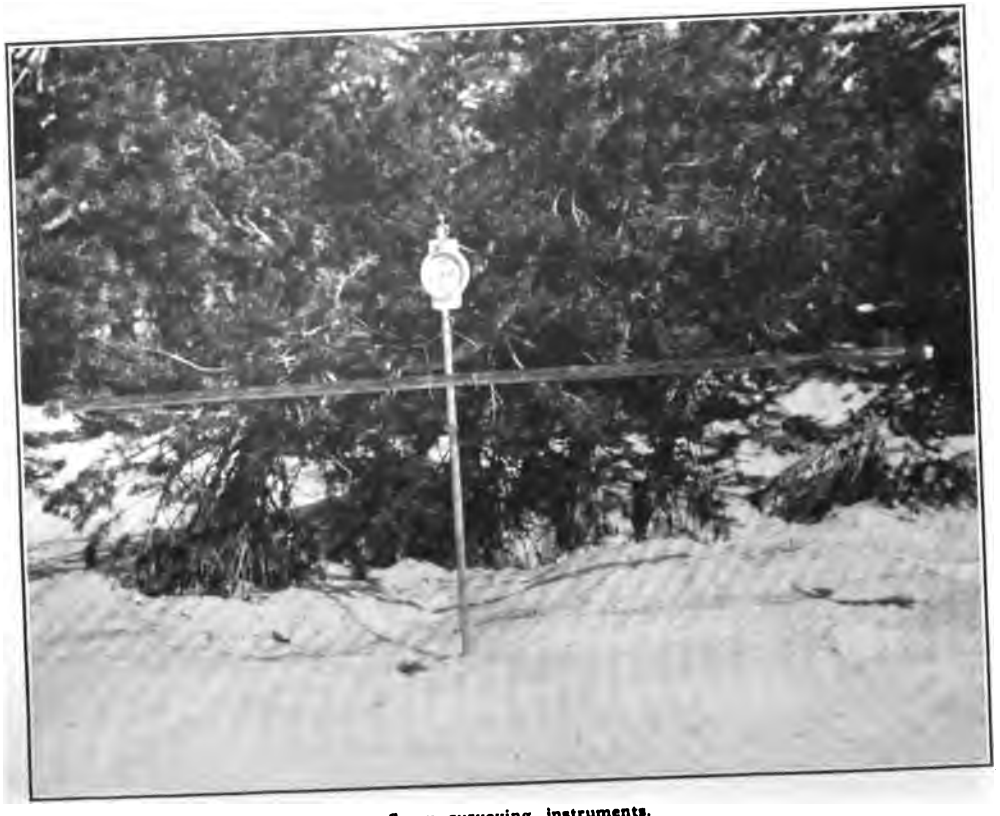
*"Conflicting Interests," page 70.

PLATE XXVII.



Meteorograph: records temperature, humidity, barometric pressure, precipitation, force and direction of wind.

PLATE XXVIII.



Snow surveying instruments.

Snow surveyor in costume.

The department holds, and has so pointed out in previous reports, that surveys of these great snow-field reservoirs should be made and the water content ascertained. From the information obtained, a forecast can be made of the quantity of water that will come down when the snow melts. Such information will be valuable, not alone in directing the operation of filling artificial reservoirs, but in giving foreknowledge of the summer flow, so that the farmer may conduct his irrigation to meet conditions. If it is known at planting time that there will be a shortage of water in June and July, crops will be planted which will not need water at that time and the limited quantity will be saved to mature fruit or other products requiring late application.

To make the prediction reliable, it is necessary to know something of the meteorological conditions prevailing before and at the time the snow was deposited. It is essential to know whether the ground was dry or saturated; whether it was warm or frozen, and many other meteorological phenomena which affect the melting of the snow.

A comprehensive snow survey then requires the use of instruments for recording precipitation, temperature, humidity and wind, as well as the water content of the snow. In the latter connection, it should be remarked that the mere measuring of snow gives no information of value. A foot of snow at one time may produce nearly a foot of water and at other times (and conditions) ten feet of snow are required for one foot of water.

The apparatus used in the determination and studies are several, and most of them must be self-recording.

A meteorograph set up and running requires attention only once a week (or longer, according to its construction), when the record-sheet must be changed. It contains a rain gage, thermometer, hygrometer and anemometer, each of which makes a continuous record upon one sheet of the precipitation, temperature, humidity, and the force and direction of the wind. The whole apparatus is enclosed in a shelter-house about four feet square.

A snow-sampler consists of a light jointed metal tube, with a cutter at one end for penetrating ice or compact snow, a scale with supporting staff to weigh the sample of snow.

To conduct a snow survey, a meteorograph, or better, more than one, if available, is set up in the field before the snows begin to fall. Regular visits are made to inspect and adjust the apparatus and change the record-sheet. After the last snowfall, and before spring thawing has set in, the snow is measured. Courses are laid out in selected portions of the field where average conditions prevail. With the tube a sample of snow from surface to bottom is taken and the amount of

water it contains is found by weighing. The scale is graduated to read direct the inches in depth of water the column of snow will produce.

By taking a great many samples on a course and having many courses laid out, distributed well over the field, a close estimate is made of the quantity of water held in storage in that field. With the result of the samplings and the knowledge gained from the meteorograph records, a fairly accurate prognosis of the progress of melting snow and resulting water flow may be made.

It is only recently that meteorologists have taken up the study of snow in its relations to the precipitation of water it represents. They have been content with reporting the depth of snow from time to time and assuming that it represents a certain amount of water.

Professor J. E. Church, Jr., of the University of Nevada, has probably given more scientific study to the subject than any other man in the United States, if not in the world. From a pure regard of the scientific aspect, and a love of nature which finds delight in communing with her in all her moods, Professor Church has prosecuted his investigations for some years, mostly alone, but more recently in co-operation with the local representatives of the U. S. Reclamation Service and the U. S. Weather Bureau.

Although convinced that the study of snowfall in its relation to stream flow is of great importance and that it is one of its proper functions, the Department of Engineering has heretofore had neither apparatus nor funds with which to make the investigations.

The legislature two years ago authorized the department to engage in this line of research, but the act did not become effective in time to do anything last winter. Upon taking up the subject, it was found that some of the instruments required are not made by any manufacturer and can only be obtained by having them made to order. Under war conditions, it was found impossible to have this done.

Fortunately, however, through the good offices of Professor Church, the department has secured enough apparatus (and practically all there is in the United States), to enable investigations to be made upon the headwaters of about seven of the principal streams of the Sierras, four of which run into the Sacramento and San Joaquin valleys, and three into the irrigated districts of Nevada.

Tentative agreements have been made for the co-operation of the United States Forest Service, U. S. Weather Bureau and Reclamation officials, as well as of some large users of water in the territory named.

Professor Church has generously placed his knowledge and experience at the service of the department, and it is felt that it is engaging upon a line of research that will result in very great good.

TOPOGRAPHIC SURVEYS.

Under an agreement between the Director of the United States Geological Survey and the Department of Engineering, the co-operative topographic survey of the state has been prosecuted during the past two years as formerly. Although the war has greatly interfered with the work, 4068 square miles were mapped since the last report. Of this, 2660 square miles were in the coast counties and 1408 square miles in the San Joaquin Valley. The work was all done as special military surveys in co-operation with the War Department, after the declaration of war.

It will be remembered that the survey of the Sacramento Valley was completed some years ago and maps are being issued showing the topography in contours of five-foot intervals.

The same kind of work is being done in the San Joaquin Valley. The field work has extended into Fresno County and maps are published covering territory as far south as Berenda.

The co-operative topographic surveys have been conducted under the supervision of Mr. Geo. R. Davis, geographer in charge of the Pacific Division, directed by Colonel R. B. Marshall, chief geographer, U. S. Geological Survey.

Their report in detail for the biennium ending June 30, 1918, here follows:

REPORT OF TOPOGRAPHIC SURVEYS IN CO-OPERATION BETWEEN THE UNITED STATES GEOLOGICAL SURVEY AND THE STATE OF CALIFORNIA, FOR THE FISCAL YEARS BEGINNING JULY 1, 1916, AND ENDING JUNE 30, 1918.

In accordance with the co-operative agreements signed July, 1916, and July, 1917, by George Otis Smith, Director, for the United States Geological Survey, and W. F. McClure, State Engineer for the state of California, the federal survey allotted $14,000 each year, and the state an equal amount, for co-operative topographic surveys in the state of California for the fiscal year ending June 30, 1917, and June 30, 1918.

The following is a summary of the field and office work accomplished during the above period under the general direction of Colonel R. B. Marshall, chief geographer, and under the immediate supervision of George R. Davis, geographer in charge of the Western Division.

From March 26, 1917, all topographic surveys in California were special military surveys in co-operation with the War Department.

FIELD WORK.

Quadrangles	Counties	Publication scale	Area mapped, sq. m.	Primary levels		Secondary traverse, miles	Triangulation	
				Miles	Permanent marks		Stations occupied	Stations marked
San Luis Creek	Merced	1:31,680	60			57	14	4
Plainsberg	Merced, Madera	1:31,680	25			25		
Lingard	Merced, Madera	1:31,680	60					
Las Garzas Creek	Merced, Stanislaus	1:31,680	7					
Bliss Ranch	Merced, Madera	1:31,680	60					
Chowchilla	Merced, Madera	1:31,680	59					
Volta	Merced	1:31,680	60			14		
Berenda	Madera	1:31,680	59					
Los Banos	Merced	1:31,680	60			86		
Sandy Mush	Merced	1:31,680	60					
Kismet	Madera	1:31,680	60					
Turner Ranch	Merced	1:31,680	60					
Elgin	Merced	1:31,680	60					
Daulton	Madera	1:31,680	70					
No. 10	Merced, Fresno, Madera	1:31,680	60			62		
San Luis Ranch	Merced	1:31,680	60					
Herndon	Madera, Fresno	1:31,680	2					
Friant	Madera, Fresno	1:31,680	6					
Kings River	Fresno	1:31,680	8					
No. 21	Madera, Fresno	1:31,680	6					
Wahtoke	Fresno	1:31,680	8	9	2			
Sanger	Fresno	1:31,680	7	8	1			
Bridge	Madera, Fresno	1:31,680	6					
Indian Gulch	Mariposa	1:62,500	147					
Gilroy Hot Springs	Santa Clara, Stanislaus	1:62,500	238	55	9	150		
Crevison Peak	Santa Clara, Stanislaus, Merced	1:62,500	118	20	4	44		
Crows Landing	Stanislaus, Merced	1:62,500	82			45		
Pozo	San Luis Obispo	1:62,500	83	46		137		
Jamesburg	Monterey	1:62,500	77			87		
Lucia	Monterey	1:62,500	95			49		
San Benito	Monterey, San Benito	1:62,500	240	31	9			
Gonzales	Monterey, San Benito	1:62,500	120	7	1			
Hollister	San Benito, Monterey, Santa Clara	1:62,500	218	48	16	120		
Bonanza	San Benito, Santa Clara, Merced	1:62,500	239	21	5			
Mount Boardman	Santa Clara, Stanislaus	1:62,500	7			9		
Adelaida	San Luis Obispo	1:62,500	234	25		251		
San Miguel	Monterey, San Luis Obispo	1:62,500	159	8	2	275		
Bradley	Monterey, San Luis Obispo	1:62,500	212			239		
Paso Robles	San Luis Obispo	1:62,500	242	17		757		
San Simeon	San Luis Obispo	1:62,500	48	16		50		
Gorda	San Luis Obispo, Monterey	1:62,500	160					
King City	Monterey	1:62,500	71			43		
Junipero Serra	Monterey	1:62,500	173			63		
Metz	Monterey, San Luis Obispo	1:62,500	10					
Bryson	Monterey, San Luis Obispo	1:62,500	142	9		145		
Totals			4,068	320	49	2,708	14	4

The following men were engaged in the field work:

Topographic Mapping.

Capt. J. P. Harrison.
Capt. E. G. Hamilton.
Capt. Wm. Stranahan.
Capt. E. H. Wilcox.
First Lieut. L. H. Connely.
First Lieut. R. T. Evans.
First Lieut. T. S. Marlor.
First Lieut. Roscoe Reeves.
Second Lieut. N. E. Ballmer.
Second Lieut. W. G. Carson.
Second Lieut. C. D. Curry.
Second Lieut. C. A. Ecklund.
Second Lieut. R. A. Furrow.
Second Lieut. N. A. Huth.
Second Lieut. E. N. Murphy.
Second Lieut. C. W. Rowell.
Second Lieut. T. P. Pendleton.
Second Lieut. R. C. Seitz.
Second Lieut. C. A. Stonesifer.
Second Lieut. K. W. Trimble.
Second Lieut. W. B. Upton, Jr.
Second Lieut. R. M. Wilson.
E. P. Davis, Topographic Engineer.
J. L. Lewis, Topographic Engineer.
S. G. Lunde, Topographer.
C. W. H. Nessler, Topographer.
J. H. LeFeaver, Assistant Topographer.
C. P. McKinley, Assistant Topographer.
G. M. Cunningham, Field Assistant.
E. Dolliver, Field Assistant.
R. A. Hamilton, Field Assistant.

Primary Levels.

Second Lieut. N. E. Ballmer.
Second Lieut. C. A. Ecklund.
Second Lieut. R. C. Seitz.
L. F. Biggs, Topographer.

Triangulation.

L. F. Biggs, Topographer.

OFFICE WORK.

The office drafting of the Little Table Mountain, Berenda, Bliss Ranch, Lingard, Turner Ranch, Chowchilla, Sandy Mush, Plainsberg, Sulphur Springs, Le Grand, Raynor Creek, Indian Gulch, Kings River, La Grange, Ingomar, Kismet, San Luis Ranch, Merced Falls, Haystack Mountain, San Joaquin River, and San Miguel topographic maps were completed and the maps transmitted for engraving. Progress in the drafting of additional sheets was made as follows: Los Banos, 45 per cent; Bradley, 85 per cent; Bryson, 5 per cent; Daulton, 10 per cent; Elgin, 80 per cent; Gorda, 70 per cent; Jamesburg, 10 per cent; King City, 10 per cent; Junipero Serra, 10 per cent; Las Garzas Creek, 10 per cent; Metz, 85 per cent; No. 10, 80 per cent; San Benito, 10 per cent; San Luis Creek, 15 per cent; San Miguel, 80 per cent; San Simeon, 30 per cent; and Volta, 80 per cent.

Primary level circuits were adjusted for the following quadrangles: Arroyo Grande, Cayucos, Jamesburg, Los Banos, Paso Robles, Sanger, San Miguel, Wahtoke, Adelaida, Bradley, Bryson, Cholame, San Simeon, and Valleton.

Geographic positions were computed for the following quadrangles: Jamesburg, Lucia, Metz, King City, Bradley, San Miguel, Bryson, San Simeon, Paynes Creek, Burney, Dixie, Prattville, Los Banos, Laguna Seca Ranch, No. 15, Elgin, No. 18, Mendota, No. 10, Sheep Ranch, No. 19, Center School, Firebaugh, Jamison, Dos Palos, No. 23, Kerman, Oxalis, Chaney Ranch, Carrisalito Springs and Tranquillity.

A SCENIC HIGHWAY.

The John Muir Trail.

John Muir was a geologist of more than national reputation and an accepted authority on glaciers and glacial action. His writings descriptive of world building, as recorded in the granites of the mountains, has done more than any other agency to call attention to the incomparable scenic beauties of the High Sierras.

In recognition of his services in making known these wonderful playgrounds of the gods, the legislature of 1915 provided for the construction of a safe trail extending along the axis of the Sierras from Mount Whitney to Yosemite Valley, and confided to the department the task of building it.

Although the appropriation made for it was inadequate to accomplish all that was desired, by enlisting the co-operation of the United States Forestry Service, and the Sierra Club, a fairly serviceable path was constructed, under the direction of the State Engineer, as stated in the last report of this department.

During 1917 the work was continued, particular attention being given to bridges and the improvement of bad stretches of trail. Owing to conditions due to the war, it was considered not advisable to attempt construction work during the year just closing.

All work of location and construction has been done under the direct charge of Forestry Service officials, to whom credit is due, particularly to Forest Supervisor W. A. Benedict, Deputy Supervisor Jordan, and Ranger John M. Hughes.

APPENDIX A.

Expenditure on Appropriations July 1, 1916, to June 30, 1918.

NOTE.—These accounts closed on, and transferred to California Highway Commission, July 27, 1917.

Chapter	Name of job	Balance, July 1, 1916	Expended	Balance, July 27, 1917
	STATE ROADS (Motor Vehicle Fund.)			
	Office expenses	$11,446 53		
	Add credit	125 00		
		$11,571 53		
	Deduct amounts transferred to other roads	1,911 53		
	Total	$9,660 00	$9,620 47	$39 53
	Alpine State Highway	$20,454 46		
	Add credits	31,718 66		
		$52,173 12		
	Deduct transfers to other roads	1,750 00		
	Total	$50,423 12	44,294 51	6,128 61
	Auburn-Emigrant Gap Road	$7,436 68		
	Add credits	23,929 55		
	Total	$31,366 23	30,552 77	813 46
	California Redwood Park Road	$4,776 22		
	Add credits	6,500 00		
	Total	$11,276 22	10,762 03	514 19
	Donner Lake Road	$10,348 12		
	Add credits	18,500 00		
	Total	$28,848 12	23,415 27	5,432 85
	Emigrant Gap Road	$10,397 20		
	Add credits	12,000 00		
	Total	$22,397 20	16,143 14	6,254 06
	Kings River Road	$3,001 66		
	Add credits	2,000 00		
	Total	$5,001 66	4,204 23	797 43
	Lake Tahoe Road	$10,501 07		
	Add credits	30,300 00		
	Total	$40,801 07	38,395 53	2,405 54
	Lassen Road	$4,269 07		
	Deduct transfer to Alpine Road	700 00		
	Total	$3,569 07	1,721 31	1,847 76
	Meyers-McKinneys Road	$7,607 29		
	Add credits	24,400 00		
	Total	$32,007 29	24,446 62	7,560 67
	Mono Lake Basin Road	$9,196 07		
	Add credits	16,000 00		
	Total	$25,196 07	18,108 03	7,088 04
	Sonora and Mono Road	$4,382 55		
	Add credits	8,200 00		
	Total	$12,582 55	9,477 89	3,104 63

APPENDIX A—Continued.

Expenditure on Appropriations July 1, 1916, to June 30, 1918.

Chapter	Name of job	Balance, July 1, 1916	Expended	Balance, July 27, 1917
	Trinity and Humboldt Road	$2,357 48		
	Add credits	11,700 00		
	Total	$14,057 48	$13,801 04	$256 44
	Tahoe City-Crystal Bay Road	$6,000 00	5,894 73	105 27
	Tioga Road	$11,337 85		
	Add credits	25,000 00		
	Total	$36,337 85	34,067 15	2,270 70
	STATE ROADS (Special Appropriation).			
678, 1915	Auburn-Emigrant Gap Road	$468 43	468 43	
120, 1913	Alpine Road	3 89	3 89	
468, 1911	Alpine Road	2 42		
469, 1911	Add credits	2 87		
	Total	$5 29	2 42	2 87
398, 1913	California Redwood Park Road	$16 77	16 77	
619, 1913	Emigrant Gap Road	1 13	1 13	
502, 1911	Kings River Road	1 80	1 80	
117, 1913	Lake Tahoe Road	2 89	2 89	
334, 1911	Lake Tahoe Road	2 78	2 78	
762, 1915	Lake Tahoe Road	6,884 55	4,061 42	2,823 13
498, 1911	Lassen Road	136 96	12 95	124 01
764, 1915	Pescadero and Redwood Park Road	10,000 00	9,601 90	398 10
765, 1915	Surprise Valley Road	235 58	164 86	70 72
680, 1915	Tahoe City-Crystal Bay Road	$3,000 00		
	Add credit	3,000 00		
	Total	$6,000 00	5,990 66	9 34
283, 1915	Yolo and Lake Road	$940 58	2 63	937 95

APPENDIX A—Continued.

Expenditure on Appropriations July 1, 1916, to June 30, 1918.

Chapter	Name of job	Balance, July 1, 1916, and appropriations	Expended	Balance, July 27, 1918
	RIVERS.			
465, 1913	Rectifying river channels	$69,308 17	$69,308 17	
664, 1915	Rectifying river channels, available 7/1/16	100,000 00	100,000 00	
377, 1917	Rectifying river channels, available 7/27/17	50,000 00	10,417 38	$39,582 62
697, 1915	San Rafael deep water channels (maintaining navigability)	12,500 00		12,500 00
25, 1911	Sacramento River flood control	29 86		29 86
503, 1909	Humboldt Bay survey	499 46		499 46
526, 1911	Mad River bank protection	7,217 41	1,937 29	5,280 12
14, 1901	Restraining debris	42,336 38	267 47	42,068 91
742, 1911	Canals and canalization of rivers	3 47		3 47
502, 1911	Eel River bank protection	50		50
	AGRICULTURAL PARK.			
443, 1913	Barns, sheds and poultry buildings	8,825 18	8,328 10	497 08
534, 1911	Dairy buildings and barns	176 43		176 43
512, 1913	Drainage and sewers	3,456 32	3,444 93	11 39
532, 1911	Grandstand	64 22	48 00	16 22
71, 1909	Machinery Hall	393 63	372 61	21 02
531, 1911	Manufactures Pavilion	564 12	294 79	269 33
533, 1911	Infield walks and improvements	189 82		189 82
221, 1915	Construction and repairs, barns and sheds	4,555 12	4,482 54	72 58
202, 1915	Women's Building	18,487 86	18,454 29	33 57
281, 1917	Improvement to grounds and erection of barns	8,500 00	8,302 12	197 88
280, 1917	Construction and repairs to buildings	5,000 00	1,697 36	3,302 64
358, 1917	Temporary pavilion	4,110 27	4,110 27	
358, 1917	Repairs to Manufactures Building	1,025 00	1,025 00	
775, 1917	Construction Agricultural Pavilion	300,000 00	33,233 75	266,766 25
Cont. 5949, 5127	Sewer, water, spur track	1,966 43	1,206 73	759 70
	ARMORIES.			
468, 1913	Armory, Los Angeles	2,982 45	2,433 73	548 72
469, 1913	Armory, Sacramento	1,410 45	415 05	995 40
549, 1913	Armory, San Francisco	1,556 42	1,556 42	
258, 1915	Armory, Naval Militia, San Diego	328 51	22 33	306 18
310, 1917	Armory, Naval Militia, San Diego	800 00		800 00
321, 1915	Armory, Stockton	22,680 85	22,574 83	106 02
	SCHOOLS.			
	California Polytechnic.			
315, 1917	Construction of barn	4,000 00		4,000 00
511, 1909	Construction of barns	24 22	24 00	22
207, 1911	Dining hall	184 14	87 50	96 64
271, 1911	Heating system	4 81		4 81
493, 1913	Heating system	10 00		10 00
270, 1911	Power, heat and light	10 21	10 00	21
291, 1915	Repairs to building and equipment	60 98	11 88	49 10
548, 1911	Repairs and improvements	2 63		2 63
492, 1913	Repairs to buildings	143 62		143 62
471, 1917	Repairs to buildings	5,000 00	4,828 39	171 61
760, 1917	Water supply	55,000 00	55,000 00	
102, 1913	Water system	298 46		298 46
290, 1915	Water supply	15,040 16	3,902 63	11,137 53
228, 1911	Water and sewer system	23 19	22 00	1 19
	Chico State Normal.			
173, 1913	Repairs and additions to heating system	79 07		79 07
234, 1915	Repairs and improvements	1,145 42	1,089 69	55 73
460, 1913	Repairs and alterations	304 06	308 30	76
282, 1917	Additions to training building	16,000 00	7,945 84	8,054 16
459, 1913	Water supply	116 95	90 56	26 39
136, 1911	Passageway	25 31		25 31
536, 1913	Street work	75 70		75 70

APPENDIX A—Continued.

Expenditure on Appropriations July 1, 1916, to June 30, 1918.

Chapter	Name of Job	Balance, July 1, 1916, and appropriations	Expended	Balance, July 27, 1918
	SCHOOLS—Continued.			
	Fresno Normal.			
207, 1915	Grounds	$6,404 89	$5,988 71	$416 18
504, 1911	Grounds	3,993 19	2,416 22	1,576 97
240, 1917	Completion of plant and equipment	17,000 00	11,709 29	5,290 71
171, 1913	Temporary buildings	101 12		101 12
393, 1915	Water supply	3,581 60	3,581 60	
393, 1915	Furnishings	1,674 00	1,674 00	
393, 1915	Clock system	943 60	830 55	113 05
516, 1913	Building and equipment	48,726 33	48,689 92	36 41
303, 1917	To pay claims of contractors	55,000 00	47,388 96	7,611 04
	Humboldt State Normal.			
204, 1915	Construction and equipment	89 55	85 13	4 42
743, 1917	General improvements	230,000 00	10,059 52	219,940 48
237, 1917	Painting temporary buildings	1,000 00	999 61	39
742, 1917	Equipment and furnishing	14,000 00		14,000 00
	Los Angeles State Normal.			
335, 1917	Additions to buildings	14,800 00	10,290 01	4,509 99
332, 1915	Addition to manual training building	126 51	124 20	2 31
416, 1911	Building and improvement fund	12 01	8 69	3 32
504, 1913	Bleacher and playground equipment	196 95		196 95
340, 1917	Improvement to grounds	10,000 00	250 00	9,750 00
334, 1917	Repairs to buildings and equipment	3,000 00	2,581 69	418 31
	Preston School of Industry.			
156, 1909	Two cottages	581 95		581 95
172, 1913	Cottages	12,999 75	12,622 51	377 24
529, 1913	Hospital	11,188 42	443 43	10,744 99
549, 1911	Concrete floor	702 43		702 43
301, 1915	Repairs	14,875 55	13,753 14	1,122 41
680, 1911	Repairs	26 79	25 75	1 04
411, 1917	Repairs and improvement	10,000 00	3,674 52	6,325 48
522, 1909	Pipe line	2 21		2 21
531, 1913	Addition to trades building	10,616 40		10,616 40
195, 1911	Water system	555 26		555 26
200, 1911	Water power plant	6 33		6 33
Cont. 3856	Club house	1,400 00	1,396 31	3 69
	San Diego State Normal.			
246, 1917	Improvements to grounds	5,500 00	5,252 78	247 22
226, 1915	Grounds	185 89	185 88	01
491, 1913	Improvement to grounds	3 35	3 25	10
524, 1911	Heating plant	18 99		18 99
308, 1917	Paving	1,500 00	30 44	1,469 56
338, 1917	Repairs and improvements	7,000 00	6,702 83	297 18
234, 1915	Repairs and improvements	236 79	236 33	46
490, 1913	Repairs	15 05	14 94	11
	San Francisco State Normal.			
491, 1917	Buildings	450,000 00		450,000 00
123, 1911	Repairs	22 63	22 61	02
421, 1913	Repairs and furnishing	31 05	31 05	
225, 1915	Remodeling buildings	209 52	183 62	25 90
Cont. 1302	Repairs	1,978 66	1,977 09	1 57
	San Jose State Normal.			
219, 1915	Outdoor classrooms	3,356 58	3,296 20	60 38
463, 1913	Gymnasium and playgrounds	13 22		13 22
426, 1913	Repairs	185 54		185 54
258, 1917	Assembly hall	80,000 00	784 46	79,215 54
243, 1915	Street improvements	9,670 87	297 45	9,373 42
193, 1911	Grounds	138 43		138 43

APPENDIX A—Continued.

Expenditure on Appropriations July 1, 1916, to June 30, 1918.

Chapter	Name of Job	Balance, July 1, 1916, and appropriations	Expended	Balance, July 27, 1918
	SCHOOLS—Continued.			
	Santa Barbara State Normal.			
295, 1915	Grounds	$10 35	$10 33	$0 02
257, 1917	Gymnasium	20,000 00	8,240 65	11,759 35
299, 1915	Machinery building	1,109 38	1,087 74	21 64
294, 1915	Repairs	519 20	487 63	31 57
546, 1911	Main building	8 56		8 56
547, 1911	Lunch room	3 73	3 17	56
250, 1917	Sewer system	1,000 00	979 97	20 03
412, 1917	Street improvement	6,000 00	6,000 00	
	California School for Girls.			
362, 1917	Trades building and gymnasium	30,000 00	359 15	29,640 85
367, 1917	Cottages	63,000 00	634 31	62,365 69
365, 1917	Heating system	1,200 00	990 66	209 34
363, 1917	Improvement of grounds	4,000 00	2,770 86	1,229 14
361, 1917	Ice plant	2,000 00	1,742 85	257 15
364, 1917	Service connections	6,000 00		6,000 00
474, 1917	Water system	10,000 00	33 95	9,966 05
239, 1915	Commissary building	1,432 52	1,286 56	145 96
318, 1915	Two cottages	5,188 91	5,184 16	4 75
241, 1915	Cottage for males	1,064 22	1,060 69	3 53
262, 1915	Drains	136 25	133 93	2 32
240, 1915	Farm buildings	1,736 16	1,688 02	48 14
319, 1915	Garage	628 32	604 73	23 59
320, 1915	Grounds	2,017 64	1,984 83	32 81
401, 1913	Construction and equipment	4,019 18	3,403 15	616 03
Cont. 2894	Water system	500 00	500 00	
	Whittier State School.			
356, 1917	Buildings	82,500 00	46,263 79	36,236 21
238, 1915	Cottages	58,304 99	58,235 63	69 36
165, 1911	Cottages	1,536 99	1,536 99	
233, 1911	Dairy barn	13 20		13 20
355, 1917	Power house	25,000 00	887 84	24,112 16
359, 1917	General repairs and improvements	2,755 00	2,715 69	39 31
357, 1917	Alterations and construction	45,000 00	22,795 59	22,204 41
427, 1913	Repairs	662 43	662 43	
317, 1915	General repairs and improvements	1,395 60	1,392 45	3 15
232, 1911	Repiping	1 23	1 23	
Cont. 1408	Water system	458 55	458 55	
Cont.	General repairs	10 20	10 20	
	HOMES.			
	California School for Deaf and Blind.			
440, 1913	Gymnasium	1,361 69	1,130 55	231 14
655, 1911	Manual industrial arts building	428 52	158 46	270 06
247, 1915	Repairs and improvements	506 87	504 59	1 28
442, 1913	Dairy barn	309 83	292 30	17 53
249, 1915	Fire escapes	1,500 00	1,474 30	25 70
248, 1915	Electric wiring	10,687 27	10,687 17	30 10
294, 1917	Electric wiring	5,000 00	4,971 82	28 18
277, 1915	Heating system	24,448 32	24,311 57	136 75
293, 1917	Heating system	21,000 00	15,545 78	5,454 22
514, 1913	Repairs and improvements	196 21	152 42	43 79
251, 1915	Repairs and improvements	496 26	489 95	6 31
348, 1917	Repairs and improvements	20,000 00	14,012 51	5,987 49
250, 1915	Development of wells	3,980 00	3,635 04	344 96
569, 1909	Plumbing, etc.	2 64		2 64
523, 1911	Water supply	8 80		8 80
	Industrial Home of Mechanical Trades for the Adult Blind, Oakland.			
418, 1913	Dormitory	971 50	659 67	311 83
419, 1913	Floors	102 69		102 69
245, 1915	Repairs	908 03	903 38	4 65
288, 1917	Improvement grounds	460 00	440 96	19 04
292, 1917	Repairs and improvements	8,700 00	8,485 46	214 54
289, 1917	Water supply	4,250 00	2,998 47	1,251 53

APPENDIX A—Continued.

Expenditure on Appropriations July 1, 1916, to June 30, 1918.

Chapter	Name of job	Balance, July 1, 1916, and appropriations	Expended	Balance, July 27, 1918
	HOMES—Continued.			
	Sonoma State Home.			
508, 1913	Cottage for epileptics	$46 78	$36 48	$10 30
509, 1913	Building for farm hands	156 55		156 55
208, 1915	Barracks	8,522 98	8,521 65	1 23
209, 1915	Improvement grounds	1,430 23	1,429 95	28
297, 1915	Water and steam piping and plumbing	16,248 11	16,240 13	7 98
434, 1913	Septic tanks	41 09	39 31	1 78
264, 1917	Cottage	15,000 00	6,166 56	8,833 44
353, 1917	Reconstruction Madrone Hall for commissary	5,000 00		5,000 00
435, 1913	Dormitory	58 34	48 30	10 04
235, 1917	Bakery building	15,000 00	423 53	14,576 47
231, 1917	Laundry building	22,500 00	500 26	21,999 74
433, 1913	Nursery for males	133 23		133 23
296, 1915	Nursery for girls	20,079 41	19,843 12	236 29
568, 1909	Power house and boiler	52 66	24 40	28 26
519, 1911	Reflooring	559 88	497 00	62 88
352, 1917	Reflooring	4,000 00	2,617 94	1,382 06
448, 1909	Repairs, Manor House	18 73	13 75	4 98
239, 1911	Water supply	27 60	27 46	14
433, 1913	Water supply	5,107 05	4,109 51	997 54
351, 1917	Steam pipe extension	8,100 00	8,085 27	64 73
	Sonoma State Home Contingent Fund—			
Est. #617	Cannery building	298 02	261 06	*36 96
Est. #1121	Tubercular hospital	3,358 64	3,306 60	*52 04
Est. #1124	Plans for development of grounds	197 52	189 02	8 50
Est. #7126, 7127	Reconstruction of barracks	5,000 00	4,989 86	10 14
Emerg. Fund, Chap. 393, 1915	Reconstruction of barracks	3,500 00	3,316 87	183 13
Cont. est. #778	Water purifier and storage tank	475 04	463 94	11 10
	Veterans' Home.			
214, 1915	Bath rooms in barracks	10,421 92	10,357 98	63 99
511, 1911	Cottage C	98 25		
511, 1911	Cottage C—credit	4 55		
		102 80	1 43	101 37
483, 1913	Dairy barn	43 09		43 09
410, 1913	Painting	36 33	30 00	6 33
482, 1913	Plumbing	990 51	987 03	3 48
213, 1915	Repairs	10,558 03	10,332 22	225 81
483, 1913	Assembly hall	176 63	81 05	95 57
212, 1915	Ten cottages	21,334 08	21,333 98	10
252, 1909	Distilling water	79 82	26 85	52 97
216, 1915	Electric wiring	3,484 88	3,434 73	50 15
236, 1911	Fire escapes	255 63		255 63
508, 1911	Grounds	102 91		102 91
486, 1909	Addition to hospital	90		90
409, 1913	Lavatories	24 65		24 65
470, 1913	Pipe line	397 43		397 43
507, 1911	Plumbing	782 89	770 26	12 63
215, 1915	Plumbing and repairs	8,139 01	3,569 70	4,569 31
508, 1909	Repairs to buildings	9 59		9 59
235, 1911	Cold storage	31 71	10 00	21 71
411, 1913	Repairs to buildings	76 75		76 75
509, 1911	Repairs to buildings	82		82
488, 1909	Storehouse and commissary	108 20		108 20
521, 1911	Septic tanks	975 34	37 60	937 74
510, 1911	Surgeon's residence	66 07		66 07
483, 1917	Boilers	15,000 00		15,000 00
395, 1917	Chapel	5,000 00	4,185 55	814 45
391, 1917	Electric wiring	2,500 00	1,014 88	1,485 12
394, 1917	Quarters for inebriates	8,000 00	3,991 82	4,008 18
426, 1917	Kitchen, etc.	4,000 00	1,306 80	2,693 20
244, 1917	Painting buildings	7,500 00		7,500 00
392, 1917	Plumbing	2,500 00		2,500 00
263, 1917	Repairs and improvements	15,000 00	6,094 62	8,905 38
243, 1917	Tubercular ward	10,000 00	3,469 32	6,530 68

*Returned to Contingent Fund Sonoma State Home.

APPENDIX A—Continued.

Expenditure on Appropriations July 1, 1916, to June 30, 1918.

Chapter	Name of Job	Balance, July 1, 1916, and appropriations	Expended	Balance, July 27, 1918
	Women's Relief Corps Home.			
248, 1917	Repairs and improvements	$5,000 00	$3,717 21	$1,282 79
	HOSPITALS.			
	Agnews State Hospital.			
400, 1913	Workers' cottage	6,521 73	1,072 60	5,449 13
473, 1913	Nurses' home	2,255 51	343 24	1,912 27
606, 1913	Wiring and steam line	38 34		38 34
307, 1917	Cottage "M"	27,000 00	1,660 20	25,339 80
332, 1917	Workers' cottage for men	45,000 00	2,685 07	42,314 93
754, 1915	Patients' cottage	22,270 52	21,984 77	285 75
Est. #689	Contingent clock system	7,637 70	7,392 83	244 87
Est. #5754	Contingent drafting	500 00	500 00	
Est. #6100	Contingent repairs, gas plant, etc	3,100 00	2,645 08	454 92
Est. #7315	Contingent well	2,000 00	1,927 57	72 43
Est. #9369	Contingent electric transformers	1,500 00	1,463 23	36 77
Est. #10854	Contingent pumping plant	1,750 00	1,749 05	95
	Mendocino State Hospital.			
107, 1913	Dam and reservoir	3,042 91		3,042 91
125, 1911	Male cottage	258 22		258 22
481, 1913	Gas plant	3 90		3 90
220, 1915	Elevators	7,402 44	7,399 07	3 37
192, 1915	Pipe line	9,235 71	8,543 26	692 45
305, 1915	Plumbing repairs	4,769 19	4,736 83	32 36
Cont. est.#7296	Alterations, administration building	6,375 00	6,048 78	*326 22
Cont. est.#869	Addition to kitchen	8,089 46	7,947 42	*142 04
Cont. est. #970	Steward's residence	575 89	551 94	*23 95
Cont. est.#985	Pipe lines, etc	1,458 86	1,310 07	*148 79
Cont. est.#891	Manager's cottage	2,501 54	2,484 15	*17 39
Cont. est.#3049	Pipe lines from power house to buildings	1,500 00	1,422 75	*77 25
Cont. est.#5825	Remodeling superintendent's residence	4,500 00	4,491 00	*9 00
Cont. est.#9407	Repairs to plumbing	750 00	738 80	*11 20
Cont. est.#984	Survey and map for plumbing and steam lines	250 00	127 31	*122 69
Cont. est.#986	Concrete conduit	538 27	523 43	*14 84
Cont. est.#1053	Inspection proposed construction	545 00	539 34	*5 66
Cont. est.#5640	Water supply	6,900 00	78 99	6,821 01
Cont. est.#1058	Electrical work	8,019 46	5,844 25	2,175 21
267, 1917	Water softening	7,500 00	74 64	7,425 36
268, 1917	Reconstruction Ward No. 7	5,000 00	310 35	4,689 65
269, 1917	Repairs, floors	2,500 00	1,814 81	685 19
325, 1917	Plumbing repairs	5,000 00	232 46	4,767 54
296, 1917	Laundry and bakery	18,000 00	16,417 30	1,582 70
326, 1917	Enlarging operating rooms	3,000 00		3,000 00
327, 1917	Reconstruction Ward No. 10	20,000 00	11,547 59	8,452 41
370, 1917	New boilers	18,000 00	6,858 17	11,141 83
371, 1917	Repairs, administration building	3,500 00	1,483 80	2,016 20
	Napa State Hospital.			
487, 1913	Dairy buildings	1,018 46	566 95	451 51
486, 1913	Dormitories and sheds	433 72	286 85	146 87
408, 1913	Credit material returned	4 81		
	Heating system	148 89		152 70
405, 1913	Laundry building	254 91	2 90	252 01
407, 1913	Cottages	2,574 35	2,314 01	260 34
489, 1909	Female cottage	319 48		319 48
505, 1911	Irrigation	4 54		4 54
314, 1909	Kitchen	51 99		51 99
404, 1913	North pay cottage	46 95		46 95
315, 1909	Receiving and treatment building	34 88		34 88
327, 1915	South pay cottage	11,072 76	11,072 24	52
488, 1913	Rewiring	73 72		73 72
489, 1913	Reclamation of low lands	780 16	709 12	71 04
352, 1915	Power house	4,461 65	4,428 56	33 09
325, 1915	Men patients' cottage	14,584 04	14,583 17	87
324, 1915	Women patients' cottage	13,388 17	13,231 75	156 42

*Returned to Contingent Fund, Mendocino State Hospital.

APPENDIX A—Continued.

Expenditure on Appropriations July 1, 1916, to June 30, 1918.

Chapter	Name of job	Balance, July 1, 1916, and appropriations	Expended	Balance, July 27, 1918
	HOSPITALS—Continued.			
	Napa State Hospital—Continued.			
328, 1915	Home for working men	$14,199 21		$14,199 21
242, 1917	Pathological laboratory	20,000 00	$698 66	19,301 34
396, 1917	Laundry machinery	6,000 00		6,000 00
397, 1917	Power house and machinery	6,000 00	5,076 65	923 35
398, 1917	Electric elevators	10,000 00	9,881 68	118 37
399, 1917	Sewer line	10,000 00	9,408 65	591 35
410, 1917	Reclamation and irrigation	6,000 00	2,756 12	3,243 88
241, 1917	Cottage for females	15,000 00	116 17	14,883 83
480, 1917	Two cottages	58,000 00	582 75	57,417 25
480, 1917	Water supply	75,000 00	47,915 46	27,084 54
503, 1911	Cold storage	49 99		49 99
406, 1913	Boilers	29		29
Cont. est.#998	Gas plant	1,200 00	1,194 19	*5 81
Cont. est.#1028	Bell tower	2,714 05	2,590 42	*122 63
Cont. est.#1027	Plans for alteration chapel	100 00	75 47	*24 53
Cont. est.#9767	Equipment for well	2,500 00	2,332 91	*167 09
Cont. est. #464	Remodeling bakery and kitchen	579 89	568 32	*11 57
Cont. est.#636	Bungalow for Dr. Ogden	663 55	639 92	*23 63
Cont. est.#783	Replace roof on laundry and survey of sewer lines	775 00	774 52	*48
Cont. est.#1267	Alterations assembly building and class rooms	5,935 00	5,935 00	
Cont. est.#2214	Power plant equipment	346 89	346 89	
Cont. est.#2928	Sewer line and heating conduit	850 00	846 94	*3 06
Cont. est.#6218	Conduit to south pay cottage	900 00	900 00	
Cont. est.#7634	Survey of pipe line	500 00	454 25	45 75
	Norwalk State Hospital.			
455, 1913	Buildings	979 81	648 95	330 86
237, 1915	Buildings	43,543 95	43,392 95	151 00
341, 1917	Bakery equipment	4,000 00		4,000 00
343, 1917	Superintendent's cottage	10,000 00	1,405 17	8,594 83
344, 1917	Farm buildings	36,700 00		36,700 00
345, 1917	Administration building	50,000 00	252 08	49,747 92
346, 1917	Three patients' cottages	135,000 00	20,843 85	114,156 15
	Southern California State Hospital.			
218, 1915	Two cottages	1,751 02	957 86	793 16
496, 1913	Laundry building	13 83	5 32	8 51
307, 1915	Water supply	7,776 84	7,719 03	57 81
336, 1917	Boilers	8,000 00	1 53	7,998 47
337, 1917	Rewiring	8,000 00	5,054 72	2,945 28
338, 1917	Cottage for disturbed patients	43,000 00	25,576 38	17,423 62
339, 1917	Pump and equipment for well	3,000 00	2,971 43	28 57
404, 1917	Nurses' home and industrial building	15,000 00	12,699 48	2,300 52
477, 1913	Four cottages	771 85		771 85
461, 1909	Physician's residence	2 16		2 16
462, 1909	Dining hall	244 27		244 27
457, 1909	Female cottage No. 2	17 00		17 00
459, 1909	Female cottage No. 3	50 90		50 90
155, 1907	Dairy barns	135 10		135 10
463, 1909	Two receiving cottages	65 64		65 64
281, 1911	Power plant	107 70		107 70
497, 1913	Reservoir	206 88		206 88
458, 1909	Storm drains	274 71		274 71
Cont. est.#1098	Chicken yards and equipment	3,500 00	3,488 76	11 24
Cont. est.#5110	Cottage No. 16	40,000 00	39,665 75	†334 25

*Returned to Contingent Fund, Napa State Hospital.
†Returned to Southern California State Hospital Contingent Fund.

APPENDIX A—Continued.

Expenditure on Appropriations July 1, 1916, to June 30, 1918.

Chapter	Name of Job	Balance, July 1, 1916, and appropriations	Expended	Balance, July 27, 1918
	HOSPITALS—Continued.			
	Stockton State Hospital.			
416, 1913	Ward No. 25	$426 22	$25 32	$400 90
309, 1915	Wiring	670 70	670 70	
792, 1917	Removal of bodies from cemetery and disposition thereof	5,000 00	31 67	4,968 33
272, 1917	Tubercular hospital	10,000 00	13 21	9,986 79
330, 1917	Cottage for disturbed patients	45,000 00	20 75	44,979 25
414, 1913	Elevators	86 09		86 09
127, 1911	Fire system	422 69		422 69
415, 1913	Heating system	83 21		83 21
197, 1911	Heating system	191 94	137 72	54 22
172, 1907	Receiving ward	18 84		18 84
126, 1911	Sewing room and dormitory	245 98		245 98
211, 1915	Boilers	1,129 92	885 33	244 59
210, 1915	Female building	22,654 50	22,088 01	566 49
310, 1915	Cottage for males	22,886 05	22,829 17	56 88
300, 1915	Farm buildings	1,826 21	1,068 99	757 22
350, 1915	Two physicians' cottages	6,358 85	6,358 85	
234, 1917	Repairs to mechanical equipment	8,000 00	7,792 96	207 04
235, 1917	Alterations to kitchen and bakery	8,550 00	8,308 22	241 78
Cont. est.#331	Repairs to steam and water supply systems	6,515 00	5,234 95	1,280 05
Cont. est.#2759	Stockton State Hospital Support Fund	700 00	654 22	45 78
	Pacific Colony.			
776, 1917	Pacific Colony for feeble-minded epileptics	250,000 00		250,000 00
	PRISONS.			
	Folsom State Prison.			
449, 1913	Cells and walls	5,301 97	822 04	4,479 93
447, 1913	Farm buildings	732 61	250 41	482 20
450, 1913	Laundry building	650 80	480 73	170 07
199, 1915	Cells, etc.	1,543 44	1,534 92	8 52
315, 1915	Power house	9,568 94	9,339 29	229 65
316, 1915	Repairs and improvements	10,122 54	10,115 51	7 03
573, 1909	Additional houses	1,347 75	1,209 11	138 64
448, 1913	Repairs	238 69	106 62	132 07
562, 1909	Warden's residence	238 78	22 15	216 63
273, 1915	Cells, etc.	16,502 32	16,448 82	53 50
313, 1915	Bake oven	5,000 00	3,427 39	1,572 61
311, 1915	Farm buildings	127 75	102 82	24 93
312, 1915	Refrigerator	4,093 85	3,819 53	274 32
254, 1917	Sewage disposal	11,000 00	9,755 76	1,244 24
276, 1917	School buildings	10,000 00	3,025 91	6,974 09
278, 1917	Repairs and improvements	25,000 00	8,718 48	16,281 52
279, 1917	Employees' cottage	10,000 00	9,147 01	852 99
279, 1917	Repairs, existing cottage	2,500 00	747 46	1,752 54
485, 1917	Boilers and power plant equipment	15,000 00	5,990 88	9,009 12
	San Quentin State Prison.			
862, 1911	Cells and walls	14,688 12	11,557 46	3,130 66
559, 1909	Guards' cottages	313 79	230 47	83 32
322, 1915	Repairs and improvements	136 41	136 41	
228, 1915	Water supply and pumping plant	4,476 37	364 54	4,111 83
258, 1917	Electrification, rewiring	3,500 00	3,400 33	99 67
283, 1917	Rewiring	32,500 00	22,802 93	9,697 07
284, 1917	Small buildings	18,500 00	8,257 37	10,242 63
285, 1917	Farm buildings	5,000 00		5,000 00

APPENDIX A—Continued.

Expenditure on Appropriations July 1, 1916, to June 30, 1918.

Chapter	Name of Job	Balance, July 1, 1916, and appropriations	Expended	Balance, July 27, 1918
	MISCELLANEOUS.			
393, 1915	Department of Engineering contingent, sixty-seventh year	$1,971 02	$1,483 51	$487 51
393, 1915	Department of Engineering contingent, sixty-eighth year	17,500 00	15,393 71	2,106 29
358, 1917	Department of Engineering contingent, sixty-ninth year	22,500 00	15,319 50	7,180 50
	Sixth District Agricultural Association.			
223, 1915	Repairs, Exposition Building	2,980 62	2,856 85	*123 77
354, 1917	Enlarging furnace and repairs, elevator	3,125 00	1,172 85	1,952 15
354, 1917	Remodeling Exposition Building	17,000 00	5,102 86	11,897 14
	State Capitol.			
368, 1917	Painting	5,000 00	3,175 57	1,824 43
603, 1913	Painting	99 00	98 12	88
582, 1913	Conservatory	45 73		45 73
538, 1913	Elevators	39 85	5 00	34 85
358, 1917	Library elevator, emergency fund	3,000 00	2,500 00	500 00
263, 1915	State Treasurer's office equipment	523 53	522 05	1 48
430, 1917	Secretary of State's office, vault equipment	4,000 00	3,151 40	848 60
762, 1917	State Printing Office building	100,000 00		100,000 00
541, 1913	San Francisco State Building	$199,887 96		
541, 1913	San Francisco State Building	800,000 00	21,479 26	978,408 70
	Appropriation	$999,887 96		
193, 1915	Governor's residence, repairs	1 64		1 64
400, 1917	Marshall's monument	4,000 00	332 31	3,667 69
	Petroleum and Gas Fund.			
759, 1917	Office buildings at Taft	4,750 00	3,142 57	1,607 43
759, 1917	Office buildings at Coalinga	4,000 00	3,913 81	86 19
	Oil Protection Fund.			
718, 1915	Garage and test house, Taft	2,500 00	125 05	†2,374 95
	Fish and Game Preservation Fund.			
	Owens River fish hatchery	$27,165 20		
	Appropriated	29,500 00	56,459 41	205 79
		$56,665 20		
Est. #556	Patrol launch	15,910 00	15,857 81	52 19
322, 1917	Monterey Theater, repairs	3,500 00	3,499 52	48
321, 1917	Monterey custom house, repairs	5,500 00	4,948 60	551 40
311, 1917	Fort Ross, repairs to buildings	1,500 00	136 50	1,363 50
679, 1915	Fort Ross, repairs, Greek chapel	3,000 00	1,975 39	24 61
480, 1913	Mission Solano, Sonoma	952 36	35 75	916 61
693, 1915	Mission Solano, Sonoma	104 12	2 00	102 12
376, 1917	Fort Sutter, electric lighting	1,000 00	999 85	15

*Returned to Sixth District Agricultural Association Fund.
†Returned to Oil Protection Fund.

APPENDIX B.

(Reprinted from Report on Iron Canyon Project, U. S. Reclamation Service, October, 1914.)

REPORT ON THE IRON CANYON PROJECT BY THE BOARD OF REVIEW.

Secretary of the Interior Franklin K. Lane appointed a board to consider the foregoing investigation of the Iron Canyon project and to report thereon. This board included representatives of the various federal and state departments actively interested in this project and its dependent features.

Brigadier General W. L. Marshall, ex-Chief of Engineers U. S. Army, and consulting engineer to the Secretary of the Interior, was chairman. Other members were: State Engineer W. F. McClure, who is ex officio engineering adviser to the State Reclamation Board and the chief state administrative officer in matters of water control and irrigation; Mr. D. C. Henny, acting chief engineer of the U. S. Reclamation Service, and Mr. H. T. Cory, consulting engineer of San Francisco, who is in this case the special representative of individual and corporate interests that will be mainly affected by the project. The board reported as follows:

Red Bluff, Cal., November 12, 1914.

To the Secretary of the Interior, Washington, D. C.

SIR: This board was appointed by you and received instructions through the Director of the Reclamation Service as follows:

> "The duties of the board are to review the report on the Iron Canyon Project presented by Mr. Hopson and his assistants, consider the various alternatives, and make such recommendations regarding them as may appear proper to you, expressing the opinion of the board if possible regarding the preference to be given to any one of the various alternatives and suggesting such further course of action as may seem wise.
>
> "If none of the alternatives appear to the board to be desirable, but further work should be undertaken along some lines not now anticipated, it will be the duty of the board to suggest further investigation. This may very properly be done with a view to bringing to the attention of Secretary Lane and to the appropriation committee of Congress an item for further surveys and examinations in connection with the work to be authorized in 1915 and 1916."

In accordance with these instruction, we have studied the report on the Iron Canyon project prepared by Mr. E. G. Hopson, supervising engineer of the Reclamation Service, dated October, 1914. This report is very able and comprehensive.

The board convened at Red Bluff, California, November 9, 1914, and visited the Iron Canyon damsite, viewed the proposed main canal locations and inspected the lands to be irrigated.

This report makes possible the comparison of ten different plans of development, all involving the irrigation of 225,000 acres of land, but differing in respect to the required storage and the important incidental features of navigation, flood control and power development.

The plans which require storage are based on building a dam at Iron Canyon, for which three heights have been considered, raising the low water respectively 112, 125 and 134.5 feet.

Provisions made for the irrigation of 225,000 acres are the same in each case, consisting of supplying 3 acre-feet of water per acre, properly proportioned through out the irrigation season, which is ample. This supply could have been furnished in full for all of the eighteen years for which records of run-off are available, except in case the plans be made to include the feature of flood control, when two years out of eighteen would have been short, only one, however, to a material extent.

In connection with the construction of a high dam at Iron Canyon a large amount of power can be economically developed.

The arguments in the Hopson report in favor of storing at Iron Canyon rather than at points upstream are convincing.

All of the plans proposed are feasible. Even on the basis of considerably higher estimates of cost, which may result from complete investigation, the cost of irrigation is far within the limits of value, provided the item of interest during construction and early years of development is not large or is absent, as assumed in the Hopson report.

Unless further investigation should reveal entirely unexpected conditions, the Iron Canyon dam can be built with safety, although its construction may, under adverse conditions, involve a larger expense than what may now appear to be a liberal estimate.

The plan calling for the least immediate outlay is the one in which no storage is provided and which proposes to draw irrigation water direct from the river flow, which at all times is ample. This plan in its main features seems the most desirable for the following reasons:

It can be built in the shortest time.

It is least involved as regards other interests.

The acreage irrigable from the project can be readily extended from 225,000 to 325,000 acres.

The rights to river flow of other interests lower down on the stream are not in any way affected by project diversions.

The plan interferes with navigation and provides no element of power development or flood control. It does, however, leave undisturbed for future utilization the Iron Canyon reservoir site. To avoid uncertainties as to water rights, federal and state legislation will be necessary.

The problem of development of the Sacramento Valley must be viewed from a broad standpoint. The interests of irrigation and navigation can not fail to be frequently antagonistic and if a policy were to be adopted permitting no irrigation that interferes with navigation, the unavoidable result would be the heavy handicapping of irrigation enterprises and a very slow and limited development. The irrigation of more than half a million acres in the upper Sacramento Valley is of an economical and political importance to the state and to the general government enormously surpassing any injury which may result to the interests of navigation. Irrigation should be unquestionably made paramount throughout the arid and semi-arid regions. Any injury to navigation from the effect of such policy in this case may well be made good by Congress through the improvement of the river channel below Sacramento in line with important work now being carried out.

The policy of using the flow of the river for irrigation irrespective of navigation is but applying in a concrete case the consensus of opinion towards which eminent members of the engineering profession familiar with conditions on the Pacific coast and men of large vision and impartial opinion throughout California have been centering for the past twenty years. Navigation interests along the Sacramento River above the city of Sacramento are now imperfectly cared for and river traffic is small and desultory. The moral effect of navigation in affecting railroad rates has quite passed since the coming into existence of the California Railroad Commission with its large and far-reaching powers. Below Sacramento the injury may be serious, but can be made good by channel deepening or by artificial works and canals.

Traffic by water from Suisun Bay to Sacramento can be cared for much better by ship canal than is possible by natural channels. Such canal would enable deep water vessels to reach Sacramento at all times.

The most desirable proposition for the Iron Canyon project is similar to plan B-3 of the Hopson report. It consists of diverting the river flow so far as needed for irrigation at some point near or above the town of Anderson. It is feasible to lay out the works so that they may ultimately irrigate all the lands on both sides of the Sacramento River below Red Bluff which can be economically served from this source without storage, possibly amounting in all to 325,000 acres or more. The cost including distributaries would approximate $55 per acre of land exclusive of interest. After completing the diversion dam and one of the main canals to Red Bluff, units could be built and added as may seem most desirable.

It is essential that the state pass an act permitting the withdrawal of the necessary water for project purposes for a period of time ample to permit full investigation, construction and gradual development. Contingent thereon Congress should enact a law which will permit the flow of the Sacramento River to be used for irrigation purposes. This last is necessary to remove doubtful water right features, not only from this project but from all irrigation enterprises along the stream.

All the land under the project is privately owned and much of it is held in large estates which should be broken up for irrigation development. This can probably be best accomplished through the agency of one or more irrigation districts, taking water from the main canals to be built by the federal and state government either singly or in co-operation.

With these conditions complied with, the project is feasible and desirable. By completely abandoning all ideas of using the water passing the Iron Canyon dam-site for any purpose except irrigation, the Iron Canyon Project can be enlarged to a total of about 800,000 acres.

It is concluded:

1 That the run-off of the Sacramento River at Red Bluff should be used as far as practicable for irrigation in the Sacramento Valley, irrespective of navigation.
2. That by means of a canal system diverting water near or above Anderson, using the natural flow of the Sacramento River, about 325,000 acres may be irrigated.
3. That by the construction of an impounding reservoir in and above Iron Canyon of about 600,000 acre-feet capacity and by using excess flow of the Sacramento in connection with the stored water a supply can be made available for an aggregate area of 800,000 acres in the Sacramento Valley.
4. That by the use of the water of the Sacramento River for irrigation and domestic supply alone as paramount to all other uses, a very large population may be supported and maintained in comfort on lands now semiarid.
5. That the Sacramento River above Sacramento can not be made an efficient navigable stream at low stages by methods of open river channel improvement, whether or not water be diverted from the river.

It is recommended:

a. That all public and state lands which may be required for the Iron Canyon Project be withdrawn or continue withdrawn from entry or sale.
b. That the state legislature pass an act permitting the withdrawal of water for the necessary time on behalf of a maximum feasible acreage to be included in the Iron Canyon Project.
c. That Congress enact a law permitting diversion of water from the Sacramento River for irrigation purposes regardless of navigation, contingent upon the state legislating as in recommendation "*b*."
d. That upon the above acts being passed the Secretary of the Interior co-operate with the state of California and with the interested organizations in rendering available the sum of $100,000 for the more complete investigation and delimitation of the project along the lines herein proposed.

(Signed) WM. L. MARSHALL,
Consulting Engineer to the Secretary of the Interior.

(Signed) W. F. MCCLURE,
State Engineer of California.

(Signed) D. C. HENNY,
Acting Chief Engineer, U. S. Reclamation Service.

(Signed) H. T. CORY,
Engineer for the Iron Canyon Project Association.

APPENDIX C.

REPORT ON THE

Utilization of Mojave River for Irrigation in Victor Valley, California

By MOJAVE RIVER COMMISSION: W. F. McCLURE, State Engineer, Chairman; J. A. SOURWINE, Engineer for San Bernardino County; and C. E. TAIT, Senior Irrigation Engineer, Office of Public Roads and Rural Engineering, United States Department of Agriculture.

(Based in part on data gathered under co-operative agreement between the Office of Public Roads and Rural Engineering, Irrigation Division, of the United States Department of Agriculture, and the California State Department of Engineering.

PREFACE.

In December, 1916, a petition was presented to the Board of Supervisors of San Bernardino County praying for the formation of an irrigation district in Victor Valley, east of the Mojave River. Under the provisions of the law, the State Engineer was called on to report upon the feasibility of the project, and he caused an examination to be made therefor.

It was found that many conflicting claims exist to the water intended to be taken for the proposed district, by lands which seem to have an equally good right to the water to those lands embraced in the proposed district.

The State Engineer, finding that in the one month allowed by law in which to make his investigation it would be impossible to ascertain whether sufficient water was available to the district for its proper development, recommended that the matter be held in abeyance until the whole question of the utilization of the waters of Mojave River could be analyzed and studied, and he suggested that a fund be provided to defray the cost of making a thorough examination.

The Board of Supervisors placed funds at the disposal of the County Engineer to pay the expenses of such an investigation to be made jointly by the San Bernardino County Engineer, the Office of Public Roads and Rural Engineering of the United States Department of Agriculture, and the State Department of Engineering.

This report is the result of the investigation and studies of the subject made under the co-operative direction of the agencies named.

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LETTER OF TRANSMITTAL.

April 30, 1918.

To the Honorable Board of Supervisors, County of San Bernardino, San Bernardino, California.

GENTLEMEN: In accordance with the instructions of your Honorable Board, we are submitting herewith a report, embodying the summary of the studies made by this commission.

Your instructions read, "This commission shall have power to make such engineering investigations as may be necessary to show the water available, the proper duty of water, the sufficiency of proposed reservoir and dam sites, and the general feasibility of the required engineering works."

It has not been deemed necessary or expedient to encumber the report with all the detail data acquired in making the investigations.

Respectfully submitted.

THE MOJAVE RIVER COMMISSION.
W. F. MCCLURE,
State Engineer, Chairman.
J. A. SOURWINE,
Engineer for San Bernardino County.
C. E. TAIT,
Senior Irrigation Engineer, Office of Public Roads and Rural Engineering, United States Department of Agriculture.

REPORT ON THE

UTILIZATION OF MOJAVE RIVER FOR IRRIGATION IN VICTOR VALLEY, CALIFORNIA.

BY

MOJAVE RIVER COMMISSION.

W. F. McCLURE, State Engineer, Chairman; J. A. SOURWINE, Engineer for San Bernardino County; and C. E. TAIT, Senior Irrigation Engineer, Office of Public Roads and Rural Engineering, United States Department of Agriculture.

INTRODUCTION.

The investigations for this report related to the following subjects: The economic problems confronting the land entrymen and settlers; the history; constructed works and future plans of the corporate enterprises; the water rights for which allowance must be made; the amount and movement of the underground water; the extent to which pumping from wells can be depended upon for irrigation; the amount of the annual surface water supply; the possible sites for storage; the possibilities of hydroelectric power development; the proper duty of water; the area for which reclamation can be safely undertaken; and the most efficient and economical plan of irrigation works.

The investigations of riparian lands are not as complete as it was desired to make them, but, considering the time and funds available, it was necessary to limit the studies in this direction.

Data were secured on all the wells in the region and the elevations of the ground surface and water surface for many of the wells were obtained by leveling from the government bench marks. This enabled hydrographic contours to be located and permitted the formulating of conclusions regarding the movement of underground water.

All records of stream discharge and of precipitation in the watershed were reviewed and correlated in arriving at the amount of water available for use.

Data on duty of water for the crops suited to the region were secured throughout Victor Valley, also from other sections of southern California with similar conditions.

Complete contour surveys were made of two possible reservoir sites which, together with private surveys of other sites, give data on all the available sites for storage.

It has not been practical to present a detailed review of the plans previously proposed for the utilization of the waters of Mojave River.

The map has been prepared from official and authentic private sources and from original surveys by the commission.

Acknowledgments.

Space does not permit acknowledgment of all the courtesies extended to the authors of this report by the many owners of wells and ditches in Victor Valley, but the commission desires to acknowledge special aid as follows: Victor H. Smith, President, Arrowhead Reservoir and Power Company, for valuable discharge measurements of Mojave River and tributaries; F. C. Finkle, Consulting Engineer for the same company, for description of the company's works; H. Hawgood, Consulting Engineer for the Mojave Water and Power Company, for useful discharge measurements of Mojave River; J. B. Lippincott, Consulting Engineer for the Victor Valley Mutual Water Association, for much data on the subject matter; John S. Thayer and Louis Evans, of the Appleton Land, Water, and Power Company, for information on the company's lands and irrigation system; F. E. Trask, Consulting Engineer for the Mojave River Irrigation District, for information as to the plans of the district; F. M. Walton, Manager of the Victor Valley Irrigation District, for information as to the plans of this district; and to Byron Waters, Attorney for ditch owners on Mojave River, for historical facts.

W. A. Johnstone and A. E. Chandler, of the California State Water Commission, visited the territory being investigated and made suggestions regarding water rights; O. E. Meinzer, of the United States Geological Survey, gave access to a report by G. A. Waring on the geology and ground waters; Charles A. Jensen, of the Bureau of Plant Industry, United States Department of Agriculture, allowed the use of apparatus for determining the wilting percentages of the soils; and C. G. Haskell, Irrigation Engineer, Office of Public Roads and Rural Engineering, United States Department of Agriculture, co-operated in the investigation of the wells.

The commission was assisted by the following: P. M. Norboe, Assistant State Engineer, assisted in organizing the field work; Robert T. Hill, Consulting Geologist, advised as to the character of some of the dam sites; F. J. Veihmeyer, Irrigation Engineer, Office of Public Roads and Rural Engineering, United States Department of Agriculture, conducted the examination of the soils and assisted in the canvass of the wells; Fred D. Bowlus, Irrigation Engineer of the same department, made the contour survey of the Mirage Valley and collected data on water rights; Porter V. Hanf, of the County Surveyor's office, San Bernardino County, had charge of the topographic surveys of the West Fork reservoir sites; H. L. Way, of the same office, collected most of the data on duty of water; Wilber D. Cook assisted in the compilation of the map; and Williams M. Humans prepared the map for publication.

Plate II, Fig. 1.—Little Bear Valley Reservoir, November, 1917, showing dam at left and gate tower at right.

Plate II, Fig. 2.—Forks of Mojave River and Mouth of Deep Creek, showing Hesperia Ditch on Side of Mountain.

Plate III, Fig. 1.—East Fork of West Fork of Mojave River above Dam Site No. 3.

Plate III, Fig. 2.—Dam Site No. 3-B, West Fork, Mojave River, looking downstream.

DESCRIPTION.

Mojave River is situated in San Bernardino County, California, and constitutes the chief drainage system of the northern slopes of the San Bernardino Mountains. The mountain headwaters comprise two distinct branches, East Fork, or Deep Creek, and West Fork, which unite at the base of the mountains to form the main river. This junction is known as the Forks. (Plate II, Fig. 2.) Below it the river, in its course 90 miles across the desert plain, receives not a surface tributary of consequence. The course of the river is first northward 30 miles, then northeastward 20 miles, and finally eastward 40 miles. The river sinks at Soda Lake at an elevation between 900 and 1,000 feet above sea level. The mountain watershed of the river, 217 square miles in area, extends from an elevation of 8,000 feet at the summit of the range to 3,000 feet at the Forks. The upper portion has heavy precipitation and the main tributaries are never dry. In summer the water sinks in the river a short distance below the Forks but appears again several miles below, reaching the Upper Narrows (Plate V, Fig. 1) at Victorville, 14 miles below the Forks. The surface flow continues through the Lower Narrows (Plate V, Fig. 2) 4 miles farther down stream and again sinks several miles below Oro Grande. The water is then brought to the surface for short distances at a number of other points, these points being farther apart and the flow of diminishing quantity toward the lower end of the stream. At places in the dry channel water may be had by digging to shallow depths. The water is generally seen at Helen 10 miles below Oro Grande and again at Hicks. The valley is confined between bluffs from the mountain to this point, but between Hicks and Barstow it widens on the northwest side. The channel is again between bluffs from Barstow to Daggett and the water is at the surface at Barstow and at Nebo, 4 miles above Daggett. Below Daggett the river crosses a broad plain. The stream is twice more between bluffs, at Camp Cady and at the Caves, and at both places the water is at the surface. The Caves are remarkable for the columnar appearance and the variegated coloring which nature has given the clay bluffs of the canyon walls. Below the Caves the channel is dry in summer.

The late winter flood water resulting from the melting of the snow always reaches to Barstow and generally to Camp Cady as an unbroken stream. Some years it reaches entirely to the broad basins of Soda and Silver lakes, which it fills to a shallow depth and in which the water gradually disappears by sinking and evaporating. The flood water generally flows to Barstow from December to April or May.

This report is concerned chiefly with the upper part of the river, including the mountain watershed and the adjacent mesas known as Victor Valley, and with the ditches having rights to water. The east

mesa is known as Apple Valley and the lower portion of this mesa bordering the river bottom is called the First Bench. The upper portion of the west mesa (Plate VI, Fig. 1) above Hesperia and stretching westward along the foothills beyond Cajon Pass is known as Baldy Mesa, the name being derived from Mount San Antonio, generally called Baldy. The lower and northern portion of the west mesa about the settlement of Adelanto is called Sunrise Valley and the section around the dry lake bed at Grey Mountain (Plate VI, Fig. 2) is called Mirage Valley.

EARLY HISTORY.

Although the history of the Mojave River country after the beginning of irrigation is more essential to this report, a few facts relating to the early period may be of interest and not out of place.

Until about the time of the Civil War the territory along the river was dominated by the Piute Indians and it was not a place of safe habitation.

Aside from the native Indians, probably among the first to explore this part of the desert were Jedediah Smith and his party of trappers from Salt Lake City, who in 1827 crossed Colorado River at the Mojave Indian villages (now Fort Mojave) and traveled westward to the course of a river, undoubtedly the Mojave, which was thereafter followed toward a pass, the Cajon, in the Coast Range en route to Los Angeles.[1] The trip was repeated the following year, but while crossing the Colorado River on a raft this party was attacked in midstream by the Indians, who had been friendly on the first trip but who had then been excited to hostility by the Spanish, and eight of the twelve members were killed. The survivors, as had the party of the previous year, crossed the desert and arrived in Los Angeles after much hardship.

Again, in 1829, Ewing Young, at the head of another party of trappers, a youthful member of which was later to be General Kit Carson, made a similar journey.[2] A member of this party has described the stream as a dry river rising in the Coast Range and leading northeast into the Great Basin, which was followed several days before water was found; also as a singular stream running southeast 200 miles and emptying into Colorado River, not two miles of its entire length in which it does not disappear, and in part resembling a line of shallow lakes. In four days after leaving the river the party arrived at San Gabriel Mission, where they were much refreshed. The river could have been none other than the Mojave, and the pass was undoubtedly the Cajon.

[1] History of the American Fur Trade of the Far West, by Capt. H. M. Chittenden.
[2] Kit Carson Days, by E. L. Sabin.

Evidently these early travelers were unaware of the sinking of the river at Soda Lake, 100 miles westward from Colorado River, and believed its course could be traced to a junction with the larger stream. Whether the emigrants who later, but prior to the fifties, traveled the Spanish or extension of the Santa Fe trail from Colorado River to Cajon Pass discovered this error is not known. Certain it is that the early official maps show a junction with the Colorado, and that the Army engineers believed them to be correct until 1853, when reconnaissance surveys were made by the War Department for a railroad from the Mississippi River to the Pacific Ocean.

That part of the survey in California was in charge of Lieutenant R. S. Williamson, who had with him William P. Blake, geologist, and 25 soldiers in command of Lieutenant George Stoneman as a military escort to guard against attack by the Piute and Mojave Indians. Lieutenant Williamson, after deciding on Tehachapi Pass as the most practical entry from the Tulare to the Great Basin, set about to locate the best route from there to the mouth of the Gila River, where his survey was, according to instructions, to join that of another party working from the east.[1]

It was reasoned that to cross the Sierra Madres to Los Angeles by the Soledad and Newhall passes would but necessitate another crossing of the Coast Range to reach the Gila. Not only was Warners Pass believed to be the only gateway from the southern California coast to the Colorado Desert, but it was also believed that by running eastward from the Tehachapi to Mojave River and then following that stream to its supposed junction with the Colorado and finally along the Colorado to the mouth of the Gila, that excellent grades would be offered. An alternate or second possible route in order of preference was to go up instead of down the Mojave River in the hope of finding a pass through the San Bernardino Mountains at the headwaters of the river which would lead to Colorado Desert with but a single crossing of the range. A route southward through Cajon Pass was not considered because it would, like a route through Los Angeles, require a second crossing at Warners Pass, understood to be impractical for a railroad.

The surveying party traveled along the north side of the Sierra Madres and arrived where the Spanish Trail from Cajon Pass reached Mojave River (probably below the Lower Narrows), October 19, 1853. Here the river is described as a broad shallow stream with valley abundantly wooded between terraced banks from one to three miles apart. The water soon sank to reappear at some point of rocks below. A detachment was sent up the river, who soon returned with the informa-

[1]Explorations and Surveys for a Railroad Route from the Mississippi River to the Pacific Ocean, Vol. V. War Department.

tion that it would be impossible to reach the Gila by the ascent of the Mojave.

Being now more confident of the preference for the river route, Lieutenant Williamson started down the river, and as he progressed found it more difficult to procure sufficient water for his mules at some of the camps, it being necessary to dig in the sands of moist places in the channel.

Finally, a canyon between clay bluffs 100 feet high, with a running stream for seven miles, evidently the Caves, was reached. Below this canyon was a sandy plain on which the channel was entirely lost, but a lake bed (Soda Lake) was observed to the north, which on examination was found to be 15 miles long and covered with an incrustation of salt and moist in places. Camp was located at springs (Soda Lake Spring), at the base of mountains near the lake bed, for headquarters for further exploration. The first lake bed was found to be connected to another (Silver Lake) two or three miles to the north of it by a ditch about 20 feet wide and 2 feet deep. This second basin, reached November 16, 1853, had a smooth floor of hard dry clay, and it, like the first, was found to have no outlet. Thereupon it was concluded that the river sank in the first basin and that the accumulating flood water when high overflowed into the second basin.

Having determined the maps showing a channel for 100 miles farther east to the Colorado River to be erroneous, Lieutenant Williamson abandoned the idea of a railroad over this route and retraced his steps to Soledad Pass, through which they went to Los Angeles and on to San Bernardino, and from which latter settlement he expected to go to Warners Pass by way of Temecula. But at San Bernardino he was informed of the existence of San Gorgonio Pass and as a second surprise found excellent grades for a railroad through this pass situated between the two highest peaks in southern California, Mount San Gorgonio and Mount San Jacinto. It is of interest to note that the Southern Pacific from Tehachapi to Yuma was constructed practically on the route finally recommended by Williamson, also that portions of the Santa Fe and Salt Lake follow in part the general route he first attempted to survey.

Emigrants, including gold seekers in '49, came to southern California through the thirties and forties from New Mexico and the East[1] over the Spanish Trail, striking Mojave River at Soda Lake Spring and following it to the Lower Narrows, thence diverging toward Cajon Pass. After the Mormons blazed the Salt Lake Trail and settled the new San Bernardino in 1851, their wagon trains increased the traffic. The freighters carried supplies from Los Angeles and San Bernardino to the mines both northward and eastward. The northward route

[1]Century Annals of San Bernardino County, by L. A. Ingersol.

branched off from the older trail at the "Forks of the Road" near where Daggett has been located. A toll road was instituted in 1862 and during the sixties regular stage service was in operation along the river.

By the late sixties stockmen, who at first only ranged their cattle in the region, risked danger of depredations by the Indians and began to live along the river. The first settlements were the stations on the trail, located where the lands were moist or where the flow of the river was sufficient for the growing of hay to feed cattle and supply the freighters. Settlements were made near the Lower Narrows and at other points down the river. Although not immediately on the trail, other choice locations settled early were just above the Upper Narrows where the Brown Ranch was started and in the valley of the West Fork, called Dunlap Valley.

The report of Lieutenant Eric Bergland, on his expedition in 1875,[1] records conditions on the river at the time. He had been instructed to examine the feasibility of diverting the Colorado River of the West from its channel for purposes of irrigation.

Starting with his party from Los Angeles, he made his outward journey to the Colorado along Mojave River, arriving at Lane's Upper Crossing, the highest station on the stream and located just below the Lower Narrows, June 29, 1875. Here the river was found to be 100 feet wide and 3 feet deep. Bergland's map shows the successive stations going down the river to have been: Point of Rocks, now Helen; Cottonwood, now Hicks; Grapevine, now Barstow; Forks of the Road, located eight miles below the site of Daggett; Camp Cady, then an abandoned military post; the Caves, and Soda Lake Spring. The eastward trail continued by way of Marl Spring and Piute Hill to Fort Mojave. The Mormon trail branched northward from the Forks of the Road. At a later time the stages, instead of following the bend of the river past Grapevine, traveled a more direct route from Cottonwood to the "Fish Ponds," located on the river between Grapevine and Forks of the Road. Another shorter but less traveled route was from Huntingtons, between the Upper and Lower narrows by way of Stoddard's Well, to Forks of the Road.

Bergland found Soda Lake nearly dry and to give mirages of perfect illusion. He states that the drainage from these saline flats is supposed to connect with Death Valley to the north, but that this had not been proven. It may now be stated that this is as much in error as the once supposed junction with Colorado River. Although some ditches were in use on the upper part of the river at the time, he makes no mention

[1]Geographical Surveys West of the One Hundredth Meridian, War Department Documents, 1876-77.

of irrigation; however, he notes having observed vegetation at Point of Rocks, Cottonwood and Camp Cady. Some of the moist lands at the stations produced hay without irrigation.

A few small ditches are believed to have been used prior to 1870 and more permanent conduits were constructed from 1873 to 1880. Some of the early settlers had no title other than possession to the lands which they occupied and they herded cattle for miles away from the river wherever feed could be found. Aside from pre-empted land in the river bottom, one of the first titles was that granted to Max Stroebel, who, in 1870, acting for an organization known as the Thirty-fifth Parallel Association, purchased from the government, under a statute then in force, about 30,000 acres on the upper part of the river. It is understood that it was the intention to establish a German colony on the land, but no such plan was carried out, and the land, although later transferred, still remains in a single corporate ownership.

ENTERPRISES.

Appleton Land, Water and Power Company.

The Appleton Land, Water and Power Company is the successor of the Hesperia Land and Water Company. The older company was organized in 1886 with an authorized capital stock of $300,000, for the purpose of supplying water to and selling the Stroebel lands which were acquired at the time of organization. The lands had originally been purchased from the government about 1870 when the public lands were, under certain conditions, sold in unlimited quantities at $1.25 per acre. The Stroebel holdings consisted of about 30,000 acres situated in the Mojave River bottom and on the west mesa, and comprised township 4 north and most of the even-numbered section of township 5 north, range 4 west. About 20,000 acres of the lands had been acquired under a single patent.

Soon about 2,000 acres, including the dam site at the Upper Narrows (Plate V, Fig. 1), were sold and the towns of Victorville and Hesperia were started. A tract of 160 acres at the forks of Mojave River, together with the water right appurtenant to it, also the claim to the surplus waters of the West Fork, were purchased. A conduit was constructed to divert water from Deep Creek at a point above the forks and convey it across the main Mojave River for the irrigation of lands in the vicinity of Hesperia on the west mesa. From the intake to the Mojave River the conduit consisted of four miles of concrete lined ditch (Plate II, Fig. 2). The water was then carried under the river by inverted siphon which, together with the extension to Hesperia, consited of five miles of 14-inch steel riveted pipe. The pipe terminated in an earthen reservoir of 58 acre-feet capacity. Some apple orchards

were planted and these, together with other crops, made a total of about 1,000 acres which were irrigated from the system at one time. The project had been launched toward the end of a period of unusual activity in the exploitation of lands throughout southern California, and as a reaction there followed a period of general depression among private corporate colonization enterprises accompanied by the complete failure of numerous state irrigation districts. During this era of litigation with its disastrous effect on irrigation securities, the Hesperia company made no further progress and was unable to finance the development of more water for the reclamation of additional land. What was most needed to make the system efficient for the lands sold and adequate for a larger area was storage of winter flood water for use in the late summer when the flow of Deep Creek was at the lowest stage. The area irrigated became smaller, and Hesperia, which had given promise of becoming a prosperous settlement, declined. The water system was operated at a loss. The steel siphon under Mojave River was washed out by flood several times, but was each time replaced, although for two years prior to the reorganization in 1911 no water was delivered at Hesperia. The cost of the irrigation works was estimated at $100,000 in 1910.

In 1911 the system was transferred to a new corporation, the Appleton Land, Water and Power Company, with an authorized capital of $300,000, of which $250,250 is issued. At the time of appraisal by the California Railroad Commission the company stated its assets to be $575,000, and liabilities $448,273. Improvements were begun, including the relining of the intake ditch, the construction of four miles of 30-inch steel riveted pipe, including the inverted siphon under Mojave River which was placed in a new location. Two miles of the old 14-inch pipe connecting the main line with Hesperia remain in place. The diversion works consist of a low concrete dam 20 feet long across Deep Creek and headgates. The capacity of the main conduit is probably 40 second-feet.

The Hesperia Water Company was organized in 1915 with a capital stock of $40,000, of which $10,500 is issued, to distribute and serve water to the town of Hesperia and to the users for irrigation under the system. The Victorville water system is still owned by the Appleton company. The Hesperia Water Company obtains the water from the Appleton company under lease and is classed as a public utility, and as such is regulated by the California State Railroad Commission. The water rate approved by the comission is 1.5 cents per hour-inch. The handling of the water sales under this subsidiary organization divorces the public service from the land colonization enterprise. In 1916 only 90 acres of apple orchard and 220 of alfalfa and corn were irrigated.

Of the Appleton Land, Water and Power Company's lands 20,000 acres are in one tract, 18,000 acres of which are commanded by the main

pipe line. Laterals would have to be extended to irrigate this area. The lands are not now being offered for sale.

The land in the Lower Narrows of Mojave River (Plate V, Fig. 2), between Victorville and Oro Grande, which has possibilities as a dam site, was at one time acquired by the predecessor of this company, but it was sold and no storage at the Lower Narrows has been seriously contemplated by these companies or others.

The company claims riparian rights to about 20,000 acres acquired from the government under one patent, also appropriation rights, one relating back to the filing for the ditch purchased, another to the filing for the Deep Creek diversion and conduit to Hesperia, another on the surplus water of the West Fork and the control of other filings made in 1911.

Arrowhead Reservoir and Power Company.

The predecessor of the present Arrowhead Reservoir and Power Company was the Arrowhead Reservoir Company, organized in 1891, the principal stockholders being Cincinnati capitalists. The original plan was a colossal undertaking. It was proposed to construct a main reservoir in Little Bear Valley which would impound the natural drainage of Little Bear Creek, a tributary of Deep Creek. An inlet tunnel, now partly constructed, was to be made from the reservoir eastward to Deep Creek and extended from this stream to Crab and Holcomb creeks to collect all drainage above the tunnel and carry it into the reservoir. Diversion dams and regulating reservoirs were to be located at Deep, Crab and Holcomb creeks and the flow of the smaller streams was to enter the tunnel through shafts. All of these works would be in the Deep Creek watershed. Another reservoir was to be constructed in Grass Valley, westward of the main reservoir and on a tributary of the West Fork of the Mojave River, and this supplemental basin was to be connected with the main basin by a tunnel. Two other reservoirs were to be located in mountain flats, the sites for which were later abandoned. Water was to be taken from the main reservoir by an outlet tunnel through the San Bernardino Range and delivered for the irrigation of lands south of the mountains. The company had no lands for sale and made no contracts for the delivery of water.

A masonry dam, to form the main reservoir, was begun on Little Bear Creek, but by the time the foundation was constructed it was found that suitable rock in sufficient quantity to construct a masonry dam was not to be had near the site. This caused a suspension of construction which was prolonged for a number of years. Data on the amount of water for storage had been meagre and the supply had been overestimated. In 1892 a series of precipitation and run-off measurements was begun throughout the watershed which was continued for 13 years before construction was resumed.

Plate IV, Fig. 1.—Dam Site No. 2, West Fork, Mojave River, looking downstream.

Plate IV, Fig. 2.—Forks Dam Site, West Fork, Mojave River, looking upstream.

Plate V, Fig. 1.—Victor Dam Site, Upper Narrows of Mojave River.

Plate V, Fig. 2.—Lower Narrows of Mojave River and intake of Driscoll Ditch.

Until 1895 the development of power had not been considered in connection with the project. About that time, when it became known that long transmission of electrical power was practicable, it was planned to utilize the energy of the water in its descent on the southern slope of the mountains.

In 1905 the property was transferred to a new corporation, the Arrowhead Reservoir and Power Company, capitalized at $6,500,000 with nonassessable stock of which $500,000 was 5 per cent preferred and the remainder common stock. Shares representing about $600,000 par value were issued and placed in the hands of a trustee, no payments having been made on these shares. Some of the stockholders have taken notes of the company for other obligations, but the company has no indebtedness outside of the stockholders.

The type of dam for the Arrowhead site was changed to a semi-hydraulic fill with concrete core. The plan of outlet works was also modified. The Burcham ranch, now called Rancho Las Flores, containing 5,240 acres and including the Forks reservoir site (Plate IV, Fig. 2) on the West Fork of Mojave River near the Forks, also two dam sites farther upstream on the West Fork and known as the West Fork sites numbers 2 and 3 (Plate III, Fig. 2, and Plate IV, Fig. 1), were acquired. It was proposed to convey the water in Little Bear Valley reservoir to the Forks reservoir, using the intervening drop for power development. The water would be combined in the forks reservoir with that received from the natural drainage of the West Fork. This lower reservoir was then to be drained by a tunnel through the mountain range to the south side, where another power drop would be located and below which the water would, as under the former plan, be delivered for irrigation in San Bernardino Valley.

About 1909 some of the owners of riparian lands on Mojave River, including the Hesperia Land and Water Company, filed suits to prevent the company diverting water from the watershed, but the cases have not been brought to trial. In 1912 application was made to the California Railroad Commission for permission to issue $4,000,000 in bonds when riparian land owners again opposed the plans of the company by protesting against the granting of the application. The application was denied, without prejudice, for the stated reason that the company's title to water was uncertain until the cases were decided by the courts. The record of the hearings conducted by the commission on the application shows the following:

Valuation put on property at time of reorganization	$1,191,000
Spent by new company since reorganization	923,204
Principal owed by new company	793,796
Interest owed by new company	126,589
Total	$3,034,589

About this time the company, or a trustee of some of the stockholders, began to purchase riparian lands on Mojave River mainly for the purpose of quieting opposition from adverse water right claimants, and 1,000 acres just below the Forks and 3,200 acres, together with most of older and more useful ditches between Victorville and Barstow, were acquired. This property included the Westwater lands below Victorville.

It had been the intention to purchase more riparian lands, but owing to the decision of the State Supreme Court about this time to the effect that flood waters of a stream could not legally be diverted from the natural drainage basin,[1] a radical change in plan was adopted which made this no longer necessary. It was now decided to use the water for the development of power and irrigation on the north side instead of the south side of the mountains. In 1914 an offer, which was not accepted, was made to the city of San Diego to sell the water from the system, the diversion from the watershed for domestic use not being illegal.

In addition to agricultural lands below the Forks, the company holds about 12,000 acres in the mountains, mainly in the Little Bear Valley, Grass Valley and Forks reservoir basins. The company claims riparian rights appertaining to the extensive lands above and below the Forks, also appropriation rights on all streams above the Little Bear Valley reservoir inlet dating from 1890 and on the West Fork and Deep Creek dating from 1905.

The company claims that the measurements show that enough water can be stored to enable the delivery of 40 second-feet continuously from the Little Bear Valley reservoir, or 100 second-feet continuously from this reservoir and the Forks reservoir combined.

The Little Bear Valley dam (Plate II, Fig. 1) is now built to a height of 160 feet above stream bed and is 80 per cent completed. It is to have a maximum height of 200 feet above stream bed and 220 feet above bedrock, a length on top of 830 feet and a top width of 20 feet. The fill will contain 1,562,329 cubic yards of earth and the core will contain 27,999 cubic yards of concrete. The original slopes were, inside 2½ to 1 and outside 2 to 1, but an addition is now being made to the lower fill to change the outside slope to 3 to 1. The core wall is 20 feet thick at the base and tapers to 3 feet thick at the top. That part above a thickness of 4 feet is reinforced. In the winter of 1909 cracks occurred in the top of the core wall which had then been built up 38 feet above the earth fill. The cracking was believed to be due to the effect of temperature on this exposed portion of the concrete. The cracks were repaired. The spillway is over the natural rim of the basin and is 5 feet deep, 100 feet wide and is to be lined with concrete.

[1] Miller & Lux *vs.* Madera Canal and Irrigation Company, 155 Cal. 60.

The Deep Creek inlet tunnel is under construction, it now being driven and partly lined from the reservoir to a point beyond Shake Creek, a length of nearly two miles. A siphon of 1,284 feet and shafts at Fern, Shake and Sheep creeks are finished. The completed tunnel will be over 14,316 feet long. The tunnel from Deep Creek to Crab Creek is to be 5,000 feet long and the Holcomb Creek extension is to add 12,100 feet. The Deep Creek dam is to be 150 feet high above stream bed, of which height 30 feet would be below the tunnel portal. The Deep Creek reservoir is to have a capacity of 2,000 acre-feet and is to act as a regulator to the inlet tunnel. The tunnel has a capacity of 600 to 1,000 second-feet, depending on the head above the intake. The Holcomb Creek dam is to be 70 feet high, giving a capacity of 1,000 acre-feet to the basin above the tunnel.

The tunnel connecting Grass Valley, 4,172 feet long, is driven and lined, but the Grass Valley dam has not been constructed. The dam as proposed is to be 90 feet high, which would give a storage capacity of 7,632 acre-feet. Water is now diverted from Grass Valley by ditch to and through the connecting tunnel into the main reservoir.

The outlet tunnel of the main reservoir, 5,102 feet long, is constructed and lined, and through it water can now be discharged into Guernsey Creek, a tributary of Deep Creek, above the intake of the Appleton Land, Water and Power Company's canal. The gate tower (Plate II, Fig. 1) is a reinforced concrete structure 185 feet high located in the reservoir basin at the upper end of the outlet. Besides the gate valves in this tower additional valves are placed in a shaft 220 feet deep extending down to the outlet in the rock rim of the reservoir. The maximum head on the outlet will be 175 feet. The maximum depth of water at the dam will be 185 feet. The capacity of the completed reservoir below the floor of the spillway will be 60,179 acre-feet when the area of the water surface will be 883 acres. About 35,000 acre-feet is now stored in the reservoir with the dam partially completed.

The fall from Little Bear Valley reservoir to the Forks is 2,000 feet, a drop sufficient to develop about 7,000 horsepower with 40 second-feet of water. The Forks reservoir site is in a position to receive, naturally, the entire flow of the West Fork, also the water from Little Bear Valley reservoir through the proposed power conduit and the flood water from the lower part of Deep Creek, provided about one mile of inlet ditch or tunnel be constructed from that stream. A dam 150 feet high across the West Fork would give a capacity of 102,000 acre-feet and a reservoir area of 2,000 acres. In addition to the main dam a saddle in the rim of the basin on the north side would have to be raised with an embankment to give this capacity.

Mojave Water and Power Company.

The project now undertaken by the Mojave Water and Power Company was first attempted by the Columbia Colonization Company, organized about 1895. It was proposed to dam Mojave River at the Upper Narrows (Plate V, Fig. 1) to impound water which would be used to irrigate the desert along the river below Victorville. An option was procured to purchase from the Hesperia Land and Water Company the dam site and the lands of the latter company that would be flooded by the reservoir to be formed.

The company failed to carry out the plan and the option, also about 16,000 acres of land along the river below Victorville, were acquired by James Westwater, who proposed to construct a tunnel from the reservoir underneath the mesa and through the San Bernardino Mountains, a distance of 22 miles, to convey part of the stored water to the southern side of the range where it would be used for the development of power and for irrigation, while some of the water was to be used to irrigate the mesa and valley lands along the river below Victorville.

The dam site and the reservoir lands of the Hesperia Company, 2,060 acres, were then purchased by I. R. Wilbur, who, together with Mr. Westwater, obtained also an option to purchase the lands of Rancho Verde that would be flooded. Mr. Wilbur then, together with Eugene de Sabla and others, in about 1908 organized the Mojave Water and Power Company, to which the property was assigned. The option on the Verde lands has been allowed to expire. A right of way was secured from the government to use the unentered land at the rocky points of the dam site for reservoir purposes.

The Victor dam site (Plate V, Fig. 1) is good, the gorge having walls of granite, and the reservoir is open to criticism only for its large area which would probably produce a heavy evaporation loss. The possibility of seepage water detouring around the west end of the dam site is not a serious objection, for some water must of necessity be allowed to flow down the river to satisfy lower riparian owners.

Tests of the underflow[1] in the narrows were made in 1894 by the United States Geological Survey. Velocities of 10 to 96 feet per day were found in the different parts of the cross section. The amount of underflow for the section of 4,160 square feet at an average velocity of 50 feet per day, and assuming the porosity of the sands at 33⅓ per cent was found to be .8 second-foot.

The elevation of the river channel at the dam site is 2,709. The United States Geological Survey made borings[2] in 1899 to determine the position of bedrock and found the maximum depth to the rock to

[1]Water Supply Paper No. 140, U. S. Geological Survey.
[2]Eighteenth Annual Report of the United States Geological Survey; Twenty-first Annual Report of the United States Geological Survey.

Plate VI, Fig. 1.—West Mesa of Victor Valley, showing yucca and San Gabriel mountains.

Plate VI, Fig. 2.—Mirage Playa and Grey Mountain.

be 46 feet. The width of the gorge at stream bed is 140 feet and at 145 feet above the stream it is 350 feet. Complete detailed surveys have been made of the dam site and reservoir basin by Mr. Hawgood for the company, from which the following capacities are taken:

80 ft. contour	75,000 acre feet
100 ft. contour	134,000 acre feet
120 ft. contour	218,000 acre feet
130 ft. contour	271,000 acre feet
140 ft. contour	350,000 acre feet

For the site to be utilized several miles of the Santa Fe Railroad would have to be moved to a new location. The railroad company has agreed to move the track to permit the building of the dam and has surveyed an acceptable route entering Victorville farther to the west by way of the arroyo.

The gigantic plan for a tunnel from the reservoir to San Bernardino Valley has been abandoned and it is now contemplated to use all the stored water on the lands on both sides of the river below the reservoir. A canal from the base of the dam would reach the mesa west of the river in a distance of about 12 miles. It is now the intention to construct the dam to about the 130-foot contour which would give an area to the full reservoir of 5,800 acres and a capacity of 271,000 acre-feet. The dam would be 345 feet long on top. According to the discharge measurements of the company and provided the water be not impounded above, also allowing 5 feet for evaporation, enough water can be stored to deliver from 100 to 140 second-feet continuously for 300 days.

Rancho Verde Company.

Rancho Verde includes 3,800 acres in the Mojave River bottom just above the Upper Narows. The first occupation was about 1867 by James Brown, a cattleman who pre-empted land and by 1874 had 1,500 acres fenced and a ditch from the river. Cole and Harris, who acquired the property about 1894, added more land by purchase, constructed another ditch, drilled wells, and started a dairy. They also incorporated Rancho Verde Company and about 1902 sold to the present owners. Until 1912 cattle had been grazed on the surrounding public range as well as on the ranch, but by this time the range was so well occupied by entrymen that the cattle were sold and the ranch has since been producing alfalfa and sugar beets. The owners claim that taxes have been paid on 1,000 miner's inches of water diverted by the ditches since 1869, and to obtain 880 miner's inches from the seven pumped wells and 350 miner's inches from the twelve flowing wells on the ranch. About 1,000 acres are now being irrigated and the ditches cover 1,500

acres, all of which has been irrigated. A portion of the land is riparian. This ranch is the most extensive of the producing properties and the company is the largest user of water on Mojave River.

Daggett Ditch.

The headworks of the Daggett Ditch were begun by the Silver Valley Land and Water Company about 1890. It was then the intention to collect the underflow of the Mojave River and convey it to the Calico mining district north of the river, near Otis (Yermo P. O.). After constructing some works at the "Fish Ponds," near Nebo, the promoters were unable to finance the completion of the enterprise and the work was resumed by the Southern California Improvement Company in 1893, who changed the plan to a ditch on the south side of the river for the purpose of irrigating land near Daggett and Minneola. A submerged dam of sheet piling driven down through the sands of the channel and into the subsurface clay was placed across the river and a tunnel or gathering flume was excavated above this dam to receive the water and deliver it to the ditch. The ditch was constructed from the intake to the Daggett ranch, a distance of four miles, and from there to the town site of Minneola, an additional six miles. The company's activities terminated with bankruptcy. In 1901 a copartnership of four persons undertook the improvement and completion of the works. The headworks which had been damaged by flood were improved, 30-inch concrete pipe was laid in the first mile of the ditch and covered with earth, and the remaining three miles of ditch leading to the Daggett ranch was lined with concrete and covered with boards. The ditch from Daggett to Minneola was abandoned.

The gathering tunnel at the intake is about one-half mile long and is timbered on top and sides. The ditch is claimed to have a capacity of 1,600 miner's inches. By agreement among the owners the Daggett ranch is entitled to the first 200 miner's inches of water secured and only this amount has been developed. An area of 250 acres on the ranch is all that is irrigated regularly under this system. Surface flood water in the river reaching the intake can be turned into the ditch and occasionally some additional land has been irrigated in this manner. The present owners claim to have spent $75,000 and each of the two companies preceding them is said to have spent a larger amount.

Yermo Mutual Water Company.

This system was initiated in 1910 by the Mojave River, Land and Water Company to supply water to about 8,000 acres of land located north of Mojave River and along the Los Angeles and Salt Lake Rail-

road below Yermo. The land had been acquired by the promoters and was to be sold by them, but in constructing a part of the system they became too heavily burdened with indebtedness to continue. The Yermo Mutual Water Company, a reorganization of the first company, was incorporated in 1916, with $160,000 capital stock, to continue the work. It is claimed that a total of about $200,000 has been spent, of which the greater part was under the first company. The works constructed consist of five 16-inch wells over 400 feet deep, of which two are equipped with 12-inch centrifugal pumps and 50-horsepower engines, three miles of concrete-lined ditch of 1,300 miner's inches capacity below the wells, then four miles of ditch of 3,300 miner's inches capacity, and two lateral ditches. It is the intention to collect underflow from the river channel and to convey it by pipe 4,400 feet to the point of enlargement in the ditch, where it is to be raised to the grade of the ditch by pumping. The company claims that 250 miner's inches can now be delivered from the two pumped wells and that more can be delivered when the settlement demands it by supplying the other wells with pumps. The water is lifted from 50 to 60 feet. Only about 200 acres are being irrigated. It is expected that alfalfa and deciduous fruits will be grown mainly. The enterprise is making but slow growth owing to lack of settlers.

Proposed Enterprises for the Use of Underflow.

Several enterprises for the development of underflow of Mojave River for irrigation have been proposed which have not progressed further than the formality of a stock incorporation and the filing of a claim on water to be appropriated, with possibly the doing of a nominal amount of work with the intention of technically establishing a right to use water relating to the date of the claim. The amount of underground water that can be diverted by gravity is largely a matter of speculation. Success in pumping from wells sunk in or near the channel at favorable locations is more certainly demonstrated. Numerous plants are operating near Hicks, Barstow, Daggett and Minneola, some of which produce good streams of water for irrigating. Several land owners pump from a trench near the river at Helen and they claim to obtain 100 miner's inches with which they irrigate 160 acres of young orchard.

LAND OWNERSHIP AND SETTLEMENT.

The territory considered in this report and shown by the map (Plate I) includes gross agricultural areas as follows:

	Acres	Acres
Mojave River bottom above Victorville		12,000
East Mesa—		
Apple Valley	32,000	
First Bench	4,000	
East of Deadman's Point	8,000	
		44,000
West Mesa—		
Baldy Mesa and Hesperia	100,000	
Sunrise Valley	70,000	
Mirage Valley	64,000	
Along river below Victorville	35,000	
		269,000
Total		325,000

Of this total 12,000 acres are patented unsold railroad grant lands, 47,000 are selected unpatented railroad indemnity lands; 17,000 acres are, or were, state school lands, and 37,000 acres are in control of the Appleton Land, Water and Power Company, the Arrowhead Reservoir and Power Company, and Rancho Verde Company, leaving 212,000 acres of public land, nearly all of which has been applied for under the Homestead and Desert Land Acts.

The railroad lands are owned by the Southern Pacific and the grant relates to the road from Mojave through Barstow to Colorado River, now controlled and operated by the Santa Fe, but which was built by the Southern Pacific about 1884. The line through Cajon Pass and Victor Valley, built by the Santa Fe in 1885, was not a land grant road. The original grant included the Southern Pacific and the Atlantic and Pacific, but the latter did not build across Mojave Desert as was contemplated. The portion of the land that should go to the Southern Pacific was in controversy until 1898 when it was decided that the railroad company was entitled to sections numbered 1, 5, 9, 13, 17, 21, 25, 27, 31 and 33 within the grant limits. The southern limit of the 20-mile strip of the grant crosses Mojave River between Oro Grande and Victorville. The southern edge of the indemnity strip, 10 miles wide outside the grant limits in which the railroad company has selected some of the odd-numbered sections, crosses the river between Victorville and Hesperia. The railroad lands have not been on the market.

Of the land applied for under the national laws, the greater area has been under the Homestead Act and a much larger proportion of the homestead entries have been patented than of the desert land entries.

The Hesperia Land and Water Company, soon after its organization, cleared some of its land of brush and timber and sold the juniper and yucca for wood. About this time many homestead filings were made and the entrymen cut the timber (Plate VI, Fig. 1) and sold wood, hauling it to Hesperia. Soon the government enforced restrictions on the cutting of timber on homestead entries which curtailed this practice and some of the entries were allowed to revert to the government.

Then came years of little activity until the present decade which brought a period of much land filing. The stimulus of the national movement for arid land reclamation, the demonstration of the feasibility of pumping south of the mountains, a better established market for apples and pears, and the activities of speculators were all influences in the rush for the public lands. Although the orchard was generally regarded as the future chief industry of the region, land entries were made for the maximum area allowed under the law and 320-acre desert entries were located where the water furnished by wells is inadequate and where pumping is too expensive for reclamation and the making of final proof.

In 1913 many of the settlers and land entrymen on both sides of the river formed the Victor Valley Mutual Water and Power District Association to secure beneficial measures, the chief one being a government irrigation project. This association was unincorporated and membership was voluntary. The members were assessed on the acre basis to provide funds to carry out the purpose of organization. The association made an urgent appeal to the government for a project to include lands on both sides of the river, but the government, although in sympathy with the end sought, was, owing to the depleted condition of the reclamation fund, unable to render financial aid. The association was instrumental in securing extensions of time for the making of final proof on land entries pending arrangements for an irrigation project to use water from Mojave River, but this offered temporary relief only.

The condition confronting many land entrymen in 1915 was discouraging. Besides the final proofs to be made, numerous small tracts had been planted to orchard on which the trees would, in a few years, need more water than could be supplied by the irrigation facilities. The total area irrigated in Victor Valley is about 7,740 acres, of which only about 2,185 acres are on the mesas.

Table No. 1 gives the areas irrigated in Victor Valley and on Mojave River. The areas irrigated from the river are close approximations and the area irrigated from wells are estimated from partial data. All ditches down to and including the Haws and Robinson are considered as being in Victor Valley.

TABLE No. 1.

Area irrigated on Mojave River and in Victor Valley.

Division	Area irrigated from river (Acres)	Area irrigated from wells (Acres)	Total acres
River Bottom and First Bench of East Mesa	1,655	3,900	5,555
East Mesa and Lucerne Valley Pass	----------	975	975
West Mesa, including Mirage Valley	310	900	1,210
Totals, Victor Valley	1,965	5,775	7,740
Lowlands	1,130	1,000	2,130
Totals, Mojave River	3,095	6,775	9,870

The Smith Act, which passed congress August 11, 1916, making possible the inclusion of government land in irrigation districts organized under the laws of the states provided such districts do not include a majority acreage of unentered land, opened the way for state irrigation districts in Victor Valley. A district to include 55,000 acres on both the east and west mesas was proposed by the association, but the land entrymen on the east mesa, believing that an independent system for their lands would be cheaper per acre than the more general project, proceeded to secure the organization of the Mojave River Irrigation District for the east side only. Soon the entrymen on the west mesa petitioned for the formation of the Victor Valley Irrigation District for the west side.

One of the main obstacles to progress is the large size of the land holdings. A majority of the entrymen can not finance the improvement of 160 and 320 acres and but few of the irrigated tracts on the mesas exceed 20 acres. If the entries were limited to 40 acres the chances for successful reclamation would be better. Small tracts planted to orchard would give more profit and more value to the land and justify more expense for water than larger tracts for other purposes. At the same time they would require less water per acre, allow a larger district to be irrigated with the water supply and make the cost of the works less burdensome. No disadvantage would be imposed on the actual settler.

MOJAVE RIVER IRRIGATION DISTRICT.

The first petition for the organization of the Mojave River Irrigation District was filed with the board of supervisors of San Bernardino County, November 20, 1916. The board, acting on the advice of the state engineer and being uncertain as to the feasibility of the proposed works and the security that could be offered for a bond issue, denied the petition without prejudice and arranged for an investigation of the conditions to be made in thirty days, intending to take final action after

being in possession of facts to enable a more intelligent decision. The petitioners could not, according to law, present a new petition until thirty days had elapsed, but it was not possible for the commission to make the necessary investigations in that time and the petitioners were unwilling to wait for the results. A new petition was then filed February 2, 1917, bearing the signatures of over 75 per cent of the landowners in the proposed district which, under the law, made it obligatory on the part of the supervisors to provide for the organization of the district. When submitted to the voters the proposal for a district carried by a vote of 40 for and none against. The organization was completed April 9, 1917.

The district embraces 27,655 acres, of which 26,874 acres are irrigable. On November 23, 1917, 11,930 acres were patented, 7,120 acres were railroad selected land and the remaining 8,615 acres were practically all entered, 75 per cent of the entered land being under the Homestead Act. It was originally the purpose of this district to purchase the Forks reservoir site of the Arrowhead Reservoir and Power Company, improve the site and construct a conduit 12 miles long of siphon, tunnel and canal to irrigate the greater portion of the district by gravity. Water would then have to be lifted 100 feet to cover the upper or southern portion of the district. Later the plans were changed and the district is now making an endeavor to combine with the Appleton Land, Water and Power Company and other landowners on the west mesa to secure the use of water from Little Bear Valley reservoir. Toward this end the district filed suit October 5, 1917, against the Arrowhead Reservoir and Power Company, and a trustee of stockholders in the company and the holders of options on their property, to condemn their entire properties and water rights.

VICTOR VALLEY IRRIGATION DISTRICT.

The first petition for the Victor Valley Irrigation District was filed May 28, 1917. The action and the reasons for the action taken by the supervisors were exactly the same as with the district for the east side, the petition being denied without prejudice. In compliance with the law a second petition was presented August 3, 1917, with a sufficient number of signatures to make it mandatory for the supervisors to provide for the organization. At the election 44 ballots were cast for and none against the organization, and the district was declared organized October 22, 1917.

The district has a total area of 71,517 acres, of which 65,000 are believed to be irrigable. About the time the organization was completed the boundary included the following classes of land: patented 34,281 acres, railroad selected land 9,417 acres, homestead entries 9,456 acres,

and desert entries 18,363 acres. No land of the Appleton Land, Water and Power Company is included.

The district controls three options to purchase all or parts of the properties of the Arrowhead Reservoir and Power Company and of a trustee of stockholders in the company. The options were obtained October 6, 1916, by C. F. Guthridge and held by him for the district to be organized. It was provided that if a district should be organized in four months of the date of the options and that if the district should take steps to exercise the right of purchase, the options were to extend for one year, or to October 6, 1917. The options were made assignable to the district only and were not to be further assigned by the district. By agreement of October 3, 1917, the options were extended to July 1, 1918, and on October 22, 1917, they were assigned by Mr. Guthridge to the district. The options are as follows:

1. For Rancho Las Flores and the agricultural lands below Victorville owned by the trustee of stockholders of the company, $750,000.

2. For all properties, including lands, constructed works, water rights, and rights of way of the company, also the right to construct a dam at the Forks site and to flood the reservoir basin on Rancho Las Flores owned by the trustee, $2,000,000.

3. For all properties of the company without the flooding privilege on Rancho Las Flores, $1,750.000.

It is proposed to exercise both the first and third options and under them to purchase for a total of $2,500,000 all the properties of the company and the trustee. The district proposes to follow one of two plans or a combination of them to carry water to the west mesa. One is for the completion of the Little Bear Valley reservoir (Plate II, Fig. 1) and the inlet works, and the construction of a conduit from the outlet of the reservoir westward across the West Fork of Mojave River and to the west mesa which would cover all land in the district by gravity. This conduit would be 27 miles long and would consist in part of tunnel at the upper end, of inverted siphon across the West Fork and of concrete pipe towards the lower end. A power drop of 810 feet would be utilized at the approach to the siphon.

The other plan is to complete Little Bear Valley reservoir, construct the power conduit to the Forks, improve the Forks reservoir site and provide for lifting the water discharged from this reservoir to the lands above the gravity conduit.

Under a combination of these plans only a part of the water in the Little Bear reservoir would be carried directly to the mesa as under the first plan, and the remainder would be dropped to the Forks reservoir. Power would then be developed on both outlets of the Little Bear reservoir and the water from the Forks reservoir would be used on the lower lands by gravity.

SOILS.

The soils of Victor Valley consist of the materials eroded from the mountains and redistributed in the valley, consequently they do not differ widely in composition but vary more in their relative proportions of sand and clay. The records of wells drilled indicate that an enormous quantity of material has been transported to the plain. The general arrangement of coarse material near the mountains outward to fine in the lower plain is not so noticeable in the surface soils as on many alluvial fans. The migratory character of the stream channels has no doubt disturbed this gradual order to some extent and the winds have also added to the complexity by transporting fine sand and dust.

In general, the higher lands are superior to the lower. That part of the west mesa known as Baldy Mesa, situated above contour 3,400, has more rain, less wind, more even temperature, more vegetation and better agricultural soil than other portions of either mesa. The foothills are covered with a thick growth consisting principally of scrub oak, manzanita and juniper, the latter extending out on the plain two or three miles. Creosote, commonly called greasewood, and sage, desert shrubs, and bunch grass, interpersed with giant yucca (*Clistoyucca arborescens*), are distributed over the entire plain. The yucca, sometimes called the Joshua tree, is peculiar to this desert and to southern Nevada, and its fantastic appearance lends a weird picturesqueness to the region (Plate VI, Fig. 1). The yucca has commercial value for the manufacture of paper, of which it makes a good grade of the manilla kind.

No comprehensive soil survey has been made of Victor Valley, but the reconnaissance for a complete survey is being made by the Bureau of Soils, United States Department of Agriculture. The soils of both mesas are well adapted to agricultural purposes.

For the purpose of studying the moisture requirements of the soils, borings were made on selected parts of the mesas to depths of 6 feet or more and soil samples were taken at each foot in depth. The samples were also used to test some other properties of the soils.

Analyses for alkali content were made of the first foot of soil from different parts of the mesas. All indicated freedom from injurious amounts of salts. No analyses were made of the subsoils, but owing to the fact that the limited amount of water for irrigation in proportion to the irrigable land will operate to make the use of water economical, it is probable that the ground water level will never be raised sufficiently to bring salts in solution to an accumulation at the surface.

Occurring on the surface and in the substrata at different points in the valley are soils containing some carbonate of lime which cements together the materials into a hardpan. It is probable that this hardpan will be softened when there is irrigation.

Soil was encountered in a number of test holes which was coarse yet hard and seemingly impervious. This appeared to consist of angular grains closely packed and held by clay particles. This soil is easily crushed and melts or softens in water without becoming plastic. This type of soil is found in rather large areas on the east mesa, but to a less extent on the west mesa, and this probably accounts for a prevailing exaggerated idea that the soils on the east mesa are much heavier than those on the west mesa. They are in general some heavier but the effect of this characteristic should be to some degree overcome by the application of water.

Table No. 2 shows the amount of organic matter in the surface soil from the different parts of the valley. The organic matter was calculated at 58 per cent of the total carbon which was quantitatively determined.

TABLE No. 2.

Carbon and Organic Content in First Foot of Soil in Victor Valley.

Number of test hole.	Kind of field	Location	Per cent of total carbon	Per cent of organic matter
1	2-year orchard	SW. cor., NW. ¼, Sec. 6, T. 4 N., R. 2 W.	.1260	.2172
2	5-year orchard	SW. ¼, NW. ¼, SW. ¼, Sec. 9, T. 4 N., R. 3 W.	.1266	.2172
6	12-year orchard	SW. ¼, SW. ¼, Sec. 30, T. 5 N., R. 3 W.	.1290	.2224
7	12-year alfalfa	NW. ¼, SE. ¼, SW. ¼, Sec. 30, T. 5 N., R. 3 W.	.1455	.2508
12	3-year orchard	NE. cor., SW. ¼, NW. ¼, Sec. 8, T. 5 N., R. 3 W.	.1365	.2353
15	5-year orchard	Center, SE. ¼, Sec. 23, T. 5 N., R. 3 W.	1.6380	2.8270
16	3-year orchard	NE. ¼, NE. ¼, Sec. 24, T. 4 N., R. 6 W.	.3075	.5301
18	1-year orchard	SE. cor., NE. ¼, Sec. 22, T. 4 N., R. 5 W.	.1500	.2586
21	11-year orchard	NE. cor., SE. ¼, Sec. 21, T. 5 N., R. 5 W.	.0795	.1370
22	3-year orchard	NE. cor., NW. ¼, SE. ¼, Sec. 22, T. 5 N., R. 6 W.	.1005	.1733

Excepting the sample from test hole No. 15, which was on subirrigated river bottom land, the soils are deficient in organic matter. This lack may be overcome to some extent by the growing of cover crops which supply humus to the soil, but such crops require some water for their irrigation in addition to that required by the main crop.

No mechanical analyses were made of the soils, but the wilting percentage was determined, and it is a measure of the texture or fineness of particle, the perviousness or degree to which it facilitates the passage of moisture and the porosity or the capacity to hold water. The finer the soil particles the "heavier" the soil, the higher the wilting percentage, the greater the quantity of water the soil must contain to support plant growth, the greater the capacity to hold water and the slower the movement of water in the soil. Although the rate of movement is slower, the final reach of capillarity is farther in the heavy soils

than in the lighter soils. The loss of moisture by evaporation should be greater from the finer textured soils.

The tests to determine the amount of moisture that should be maintained in the soils to sustain plant growth are useful in comparing the two mesas as to their relative requirements of water. This study was made according to the method developed and used by the Bureau of Plant Industry of the United States Department of Agriculture. The purpose was to determine what is designated as the wilting percentage of the soils. This term is expressed in percentage by weight on the basis of the weight of the dry soil and it may be defined as the percentage of moisture in the soil below which, if the moisture drops, the plants will wilt. It has been determined by experiment that the finer the texture of the soil the greater the percentage of this unavailable moisture. It is apparent that for good plant growth and profitable crop production the moisture should not be allowed to fall below the wilting percentage during the growing season. The wilting percentage, if multiplied by 1.84, gives what is known as the moisture equivalent. The percentage of moisture which corresponds to this is that usually found in the soil after an irrigation and probably may be considered an optimum.

Tables No. 3 and No. 4 give the wilting percentages and the moisture equivalents for soils tested from the east and west mesas. The amounts of water necessary in the soil to prevent wilting of plants and to satisfy the moisture equivalent shown in the two last columns were calculated on the basis of an assumed volume weight of soil of 90 pounds per cubic foot.

TABLE No. 3.

Wilting Percentages and Moisture Equivalents for Six Feet of Soil on East Mesa.

Number of test hole	Location	Average wilting percentage	Average moisture equivalent in per cent	Acre feet per acre to prevent wilting	Acre feet per acre for moisture equivalent
1	SW. cor., NW. ¼, Sec. 6, T. 4 N., R. 2 W.	5.4	9.8	.462	.846
2	SW. ¼, NW. ¼, SW. ¼, Sec. 9, T. 4 N., R. 3 W.	6.1	11.1	.521	.959
3	SW. ¼, NW. ¼, SW. ¼, Sec. 9, T. 4 N., R. 3 W.	3.6	6.6	.309	.570
6	SW. ¼, SW. ¼, Sec. 30, T. 5 N., R. 3 W.	8.6	15.8	.743	1.145
11	SE. cor., Sec. 22, T. 5 N., R. 3 W.	3.0	5.5	.258	.474
12	NE. cor., SW. ¼, NW. ¼ Sec. 8, T. 5 N., R. 3 W.	7.2	13.0	.617	1.124
13	SE. cor., SW. ¼, NW. ¼, Sec. 8, T. 5 N., R. 3 W.	9.6	17.7	.838	1.529
14	SW. ¼, SW. ¼, Sec. 33, T. 5 N., R. 3 W.	4.3	8.0	.374	.691
	Average	6.0	10.9	.515	.917

TABLE No. 4.

Wilting Percentages and Moisture Equivalents for Six Feet of Soil on West Mesa.

Number of test hole	Location	Average wilting percentage	Average moisture equivalent in per cent	Acre feet per acre to prevent wilting	Acre feet per acre for moisture equivalent
16	NE. ¼, NE. ¼, Sec. 24, T. 4 N., R. 6 W.	6.1	11.1	.522	.959
17	SW. cor., SW. ¼, Sec. 18, T. 4 N., R. 5 W.	4.4	8.0	.377	.691
18	SE. cor., NE. ¼, Sec. 22, T. 4 N., R. 5 W.	5.8	10.6	.497	.914
19	SE. cor., NW. ¼, Sec. 22, T. 5 N., R. 5 W.	6.3	11.5	.542	.994
21	NE. cor., SE. ¼, Sec. 21, T. 5 N., R. 5 W.	3.1	5.8	.272	.497
22	NE. cor., NW. ¼, SE. ¼, Sec. 22, T. 5 N., R. 6 W.	8.1	15.3	.710	1.322
24	SW. cor., NW. ¼, Sec. 4, T. 5 N., R. 6 W.	5.2	9.6	.464	.838
25	SE. cor., NE. ¼, Sec. 23, T. 6 N., R. 7 W.	3.0	5.5	.261	.474
	Average	5.3	9.6	.456	.836

In sampling it was noticed that in all except No. 14, which was in an unirrigated orchard on Baldy Mesa, the soil was dry below the third or fourth foot.

The test for the first 6 feet of soil in eight holes on the east mesa gave wilting percentages ranging from 3.0 to 9.6 per cent, with an average of 6.0 per cent. Similar tests for eight holes on the west mesa gave wilting percentages ranging from 3.0 to 8.1 per cent with an average of 5.3 per cent. The number of acre-feet of water per acre that would have to be put into the upper 6 feet of soil on the east mesa to produce a moisture percentage above the wilting point is .52, and the number of acre-feet to produce the same result on the west mesa is .46. It is assumed that a depth of 6 feet of soil is sufficient for the penetration of roots of deciduous fruit trees. The surface soil on the east mesa in considerable areas is "heavier" than that on the west mesa where the "heavier" textured soil is more in spots. This theoretical comparison indicates that the soils of the east mesa would require but slightly more water than those of the west mesa.

These results do not show the duty of water nor give data from which the duty of water may be determined. They merely compare the soils as to moisture requirements. They do not show how rapidly the moisture, if once supplied, would be depleted by the action of nature nor how frequently and in what amounts water would have to be supplied to maintain the required moisture percentages. These studies take account of soils only and do not give consideration to other important factors affecting duty of water.

CLIMATE.

In a study of duty of water due consideration must be given to elevation and topography as affecting precipitation, temperature and wind as affecting evaporation, and to the possibility of deep percolation.

Table No. 5 gives the maximum and minimum temperatures recorded at the ranch of Dr. G. W. Dobie, centrally located on the west mesa.

TABLE No. 5.

Temperatures in Degrees Fahrenheit at Dobie Ranch, Victor Valley.

	1909		1910		1911		1912		1913		1914		1915		1916	
	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum
January	70	26	68	12	60	16	68	14	64	12	66	22	58	24	65	18
February	66	26	69	12	58	19	68	18	67	21	64	26	62	28	75	19
March	72	25	84	30	84	24	67	29	85	20	76	30	74	34	88	30
April	89	38	94	34	84	24	78	29	93	32	82	33	86	30	91	39
May	98	40	109	38	86	35	92	38	97	28	97	38	98	40	96	36
June	106	47	105	42	106	42	106	42	100	40	106	----	105	42	109	40
July	111	49	108	46	106	52	106	46	108	50	106	----	----	----	103	47
August	102	52	106	54	107	50	108	50	106	50	110	----	106	61	----	----
September	102	40	100	50	102	43	98	40	98	38	96	----	102	42	----	----
October	83	44	91	34	78	36	----	----	86	28	86	----	94	40	----	----
November	76	30	78	26	74	16	70	30	74	22	72	22	89	18	----	----
December	67	12	68	24	64	14	58	14	60	20	50	16	70	18	66	16

The highest temperature in the foregoing table is 111° which occurred in July. The lowest, 12°, occurred several times in the months of December, January and February. The lower parts of the valley have greater and the higher parts less extremes of temperature. The minimum winter temperature at Victorville has fallen below zero on occasions.

The annual rainfall in Victor Valley varies from about 15 inches at the foothills to about 5 inches at Victorville. The clouds come from the south or southwest and they enter the valley through Cajon Pass and by crossing over the mountains on either side of the pass. They are sometimes turned westward from Cajon Pass and this probably accounts for a precipitation on Baldy Mesa that is greater than would be accounted for by elevation alone. Generally an annual rainfall of 8 or 9 inches is required to satisfy the immediate surface run-off and the evaporation from the soil and the precipitation must generally exceed this amount for any considerable quantity of moisture to be retained in the soil long enough to produce other than characteristic desert vegetation. This appears to hold true for this locality where the greater precipitation on Baldy Mesa produces the heavier and more varied plant forms of the Juniper belt.

Table No. 6 gives the only measurements of precipitation that have been kept long enough to be of value.

TABLE No. 6.

Precipitation in Victor Valley.

Season	Forks, elevation 3,000 feet (Inches)	Hesperia, elevation 3,190 feet (Inches)	Dobie Ranch, elevation 3,130 feet (Inches)	Rancho Verde, elevation 2,760 feet (Inches)	Victorville, elevation 2,736 feet (Inches)	Barstow, elevation 2,150 feet (Inches)
1904–1905		12.42			6.70	5.90
1905–1906	14.94	4.78		6.71	5.89	1.80
1906–1907	25.77	13.44		10.72	8.61	
1907–1908	9.14	9.38		6.28	5.75	7.06
1908–1909	9.94	5.21	3.35	5.19	4.94	4.81
1909–1910	17.14	8.99	2.85	6.16	4.47	4.16
1910–1911	11.75	8.21	3.84	5.72	3.25	2.90
1911–1912			3.77	5.82		3.31
1912–1913			3.50	2.72		
1913–1914			6.76	7.27		
1914–1915			6.91			
1915–1916			8.40			
Average	14.75	8.91	4.30	6.29	5.66	4.27
Number of seasons	6	7	8	9	7	7

The variation in annual precipitation at the several stations is graphically shown by the diagram Fig. 1.

Unfortunately no records of rainfall have been kept for periods of several years on the east mesa but such meagre records as are available indicate the rainfall to be less than on the west mesa. This difference has been observed by residents of the valley and it is also shown by the vegetation.

Almost no rain falls in June and July and about 75 per cent of the total annual precipitation occurs in December to April, inclusive. Some snow falls in winter, especially on the upper slopes of the plain. The monthly distribution of the annual precipitation at the Dobie Ranch is shown by Table No. 7, also by the diagram Fig. 2.

TABLE No. 7.

Monthly Precipitation at Dobie Ranch.

Month	1912-13 (Inches)	1913-14 (Inches)	1914-15 (Inches)	1915-16 (Inches)	Mean 1908-09	(Inches) 1909-10	(Inches) 1910-11	(Inches) 1911-12	Mean (Inches)
July		0	0	0	0	.30	0		.04
August		.90	.05	0	0	.13	0	0	.13
September	.40	0	0	1.74	1.01	0	0	0	.39
October	.76	0	0	.10		0	.36	0	.15
November	0	.15	.10	0	.18	.67	.22	.10	.18
December	.38	1.18	.08	.15	0	.08	2.23	.22	.53
January	.60	.32	1.38	0	.87	3.17	1.19	2.56	1.26
February	.20	0	1.48	0	1.26	1.08	2.18	.36	.81
March	1.01	.30	.61	1.48	.08	.05	.07	.05	.46
April	0	0	.18	.30	0	1.28	.40	0	.26
May	0	0	.01	0	0	.10	.26	.11	.06
June	0	0	0	0	.10	0	0	0	.01
Season	3.35	2.85	3.84	3.77	3.50	6.76	6.91	3.40	4.27

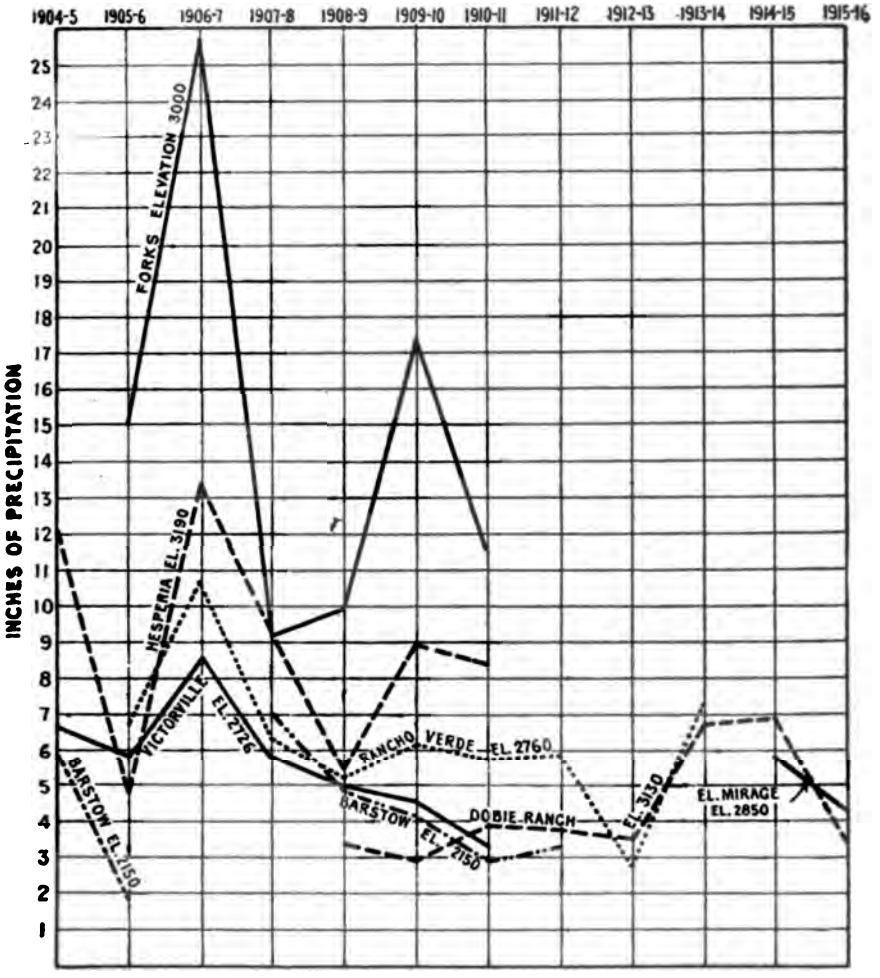


Fig. 1.—Diagram of comparison of annual precipitation at stations in Victor Valley.

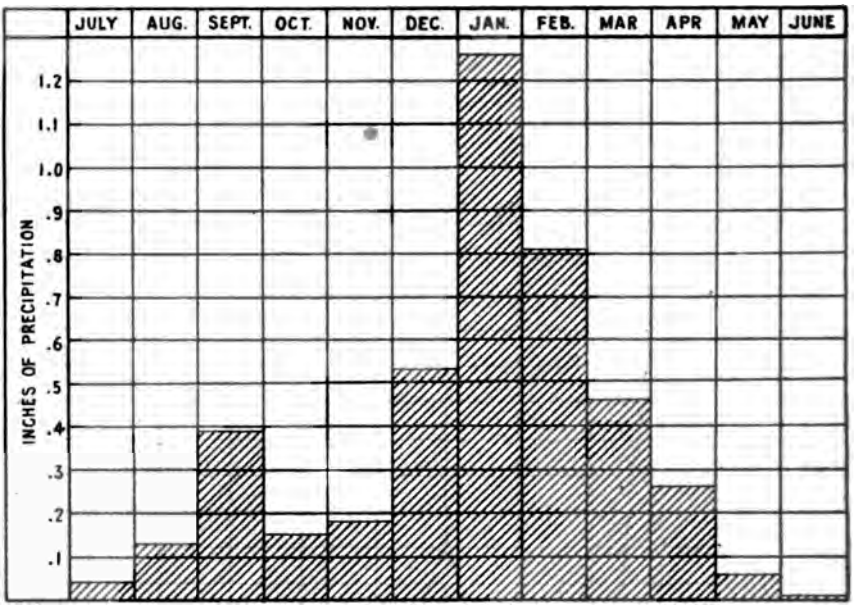


Fig. 2.—Diagram of mean monthly precipitation at Dobie Ranch.

This is a region of much wind. The prevailing direction is from south of west. The Baldy Mesa is most free from wind. The stronger air currents occur more frequently in the spring. The winds, together with the dry atmosphere, should produce high evaporation losses from either water surfaces or wetted soils. The Fourth Annual Report of the Los Angeles Board of Water Commissioners gives the evaporation from a water surface in this section at 56.40 inches for June to December, inclusive, 1898, and an estimate of 86.55 inches is given for the entire year. The Arrowhead Reservoir and Power Company has found the evaporation from Little Bear Valley Reservoir in the mountains to be from 30 to 36 inches per annum. A comparison of these records shows the effect of the desert atmosphere, temperatures and winds on evaporation.

DUTY OF WATER.

An advantage is to be gained by selecting crops such as apples and pears that are not only suited to soil and climate of Victor Valley, but which also have high commercial value and require little water. It is, in fact, imperative that the greater part of the land to be under any irrigation system on either mesa grow crops that permit both a high duty of water and a high cost of irrigation per acre in order that the project be financially feasible. It is assumed that a small portion of the land would produce alfalfa and vegetables but the proportion of these should

not be large. Alfalfa in this region would require more than double the amount of water required by deciduous fruits and the area served by the water available if planted to alfalfa would then be less than half the area that could be served if planted to orchard. Finally, the cost per acre of the works for alfalfa would practically be double that for orchard for the cost of the distributing system on the mesa would be small in proportion to that of the mountain works which latter cost would be the same in either case.

No attempt was made to systematically collect information on the duty of water for alfalfa for this report as was done for duty for deciduous fruits, but opportunity was given in the course of the investigation to obtain some miscellaneous data which are presented for what they are worth in Table No. 8.

TABLE No. 8.

Duty of Water for Alfalfa.

Number of tract	Locality	Acres	Acre feet	Acre feet per acre
1	Mojave River bottom	60	960.00	16.00
2	Mojave River bottom	66	1,040.82	15.77
3	East Mesa	40	274.40	6.89
4	West Mesa	5	6.20	1.24
5	West Mesa	25	100.00	4.07
6	Lucerne Valley	18	39.60	2.20
7	Lucerne Valley	40	109.20	2.73
8	Lucerne Valley	17	46.24	2.72
9	Perris Valley	75	421.50	5.62
10	Perris Valley	50	303.50	6.07
11	Perris Valley	30	191.70	6.39
12	Perris Valley	50	275.00	5.50
	Totals and average	476	3,768.16	7.92

The average 7.92 acre feet per acre is obtained by dividing the total number of acre feet, 3,768.16, by the total number of acres, 476, which gives weight in the average to the several tracts according to area. Eliminating tracts numbers 1 and 2, which are in the river bottom where the soil is sandy and the water plentiful and cheaply applied, the average is 5.72 acre feet per acre which amount is believed more than is necessary for alfalfa in Victor Valley.

A better idea of the amount of water required for irrigating alfalfa may be had from consideration of two of the larger alfalfa growing sections of southern California, Imperial Valley and Chino, the one more arid and the other less arid than Victor Valley. The water used in Imperial Valley flows by gravity from Colorado River and is plentiful and cheap. That used at Chino is pumped from wells with lifts up

to 125 feet and is expensive. The fields in Imperial Valley are flooded by the border check method and those at Chino are flooded by surface pipe. The duty of water for alfalfa in these localities is shown by Table No. 9.

TABLE No. 9.

Duty of Water for Alfalfa in Imperial Valley and at Chino.

Locality	Number of crops	Rainfall in acre feet per acre	Irrigation in acre feet per acre	Total water in acre feet per acre	Irrigation per crop in acre feet per acre	Total water per crop in acre feet per acre
Imperial Valley	8	.25	4.00	4.25	.50	.53
Chino	6	1.25	2.50	3.75	[1].50	.62
			3.25	4.00	.50	.57

[1]The first crop at Chino is unirrigated.

Four crops and sometimes a light or partial fifth crop of alfalfa are cut per annum in Victor Valley. If .5 foot in depth of water be applied to produce each crop the total amount that would be required is 2 or 2.5 acre feet per acre.

Apple and pear orchards in Victor Valley have generally been irrigated four times per annum, the first being in April or May and the last in October. In some cases a fifth irrigation has been given in November. Most of the orchards appear to have had insufficient water and it is probable that under an efficient irrigation system the practice would be to give five irrigations, unless rain is plentiful in the first half of the winter.

In order to arrive at a proper duty of water for deciduous fruits data were obtained on the use of water on all orchards in Victor Valley where the amount applied was measured or where records of value were kept. Data were also secured on orchards in other sections of southern California where somewhat similar conditions obtain. The elevation and climate of the settlements on the north side of the Sierra Madre range, including Victor Valley, closely resemble. Some of those on the south side differ more from Victor Valley in certain respects as with reference to precipitation at Beaumont and Yucaipa and to plentiful water supply at Banning, but they are in general comparable. Other things being equal, records from Victor Valley should be given more weight than records from other sections, and data on mature orchards more truly indicate the amount of water that would eventually be required on the mesa, but, unfortunately, there are as yet only a few producing orchards in Victor Valley, so that the records from the greater number of older orchards in the other deciduous fruit sections must be relied upon to a large extent.

The results for each of the localities investigated are given in the following tables. The average duty of water in acre-feet per acre for each locality is determined from the total number of acres and the total amount of water applied, thereby giving weight according to acreage in making the average.

TABLE No. 10.

Mojave River Bottom.

Duty of Water for Deciduous Orchards. Mojave River Bottom.

Number of tract	Kind of orchard	Age of trees	Acres	Acre feet	Acre feet per acre
1	Apples	20	15	38.25	2.55
2	Pears	1	6	11.88	1.98
	Totals and average		21	50.13	2.39

East Mesa.

Number of tract	Kind of orchard	Age of trees	Acres	Acre feet	Acre feet per acre
3	Apples	12	30	171.60	5.72
4	Apples	3	140	61.60	.44
5	Apples and pears	3-5	75	62.25	.83
6	Apples and pears	4	75	123.75	1.65
7	Apples and pears	4	40	28.00	.70
8	Apples and pears	1-2	54	71.80	1.33
9	Apples and pears	1-2	40	39.60	.99
10	Apples and cherries	3	56	39.76	.71
	Totals and average		510	596.36	1.17

West Mesa.

Number of tract	Kind of orchard	Age of trees	Acres	Acre feet	Acre feet per acre
11	Apples	20	10	8.10	.81
12	Apples	20	8	2.88	.36
13	Apples	20	12	12.36	1.03
14	Apples	20	20	18.20	.91
15	Apples	20	20	29.80	1.49
16	Apples	4	30	6.90	.23
17	Apples	1-6	10	2.00	.20
18	Apples and pears	3	55	28.60	.52
19	Apples	4	40	8.80	.22
20	Apples	2	20	4.40	.22
21	Pears	3	40	8.80	.22
	Totals and average		265	130.84	.49

Lucerne Valley.

Number of tract	Kind of orchard	Age of trees	Acres	Acre feet	Acre feet per acre
22	Apples	8	8	2.48	.31
23	Apples and pears	8	20	16.60	.83
24	Pears	2	40	40.80	1.02
	Totals and average		68	59.88	.88

Yucaipa.

Number of tract	Kind of orchard	Age of trees	Acres	Acre feet	Acre feet per acre
25	Peaches	10	6	17.34	2.89
26	Apples	8-12	3	8.67	2.89
27	Apples	4	10	3.60	.36
28	Apples, cherries, pears	4-20	20	35.60	1.78
	Totals and average		39	65.21	1.67

San Timeteo Canyon.

Number of tract	Kind of orchard	Age of trees	Acres	Acre feet	Acre feet per acre
29	Peaches	6	20	7.20	.36
30	Apricots	20	15	7.20	.48
	Totals and average		35	14.40	.41

Perris Valley.

Number of tract	Kind of orchard	Age of trees	Acres	Acre feet	Acre feet per acre
31	Apricots	1	10	4.20	.42
32	Apricots	3	10	6.80	.68
33	Apricots	1	10	9.40	.94
	Totals and average		30	20.40	.68

Beaumont.

Number of tract	Kind of orchard	Age of trees	Acres	Acre feet	Acre feet per acre
34	Apples	4–7	100	42.00	.42
35	Apples	3–6	10	3.60	.36
36	Apples, peaches, pears	5–8	8	2.88	.36
37	Apples	5	5	2.40	.48
38	Apples, pears, cherries	5	5	1.20	.24
39	Apples	7	5	1.80	.36
40	Apples and cherries	5	11	2.42	.22
41	Cherries, pears, apples, peaches	5	5	1.20	.24
42	Apples	5	5	1.80	.36
43	Apples	5	5	1.80	.36
44	Apples, pears, peaches, cherries	7	5	.85	.17
45	Apples	3	8	3.60	.45
	Totals and average		172	65.55	.38

Banning.

Number of tract	Kind of orchard	Age of trees	Acres	Acre feet	Acre feet per acre
46	Apricots and almonds	Over 5	15	16.05	1.07
47	Apricots, peaches, almonds	25	20	31.80	1.59
48	Apricots and peaches	8	15	29.70	1.98
49	Apricots, peaches, almonds	6–9	20	12.00	.60
50	Apricots	5	8	19.68	2.46
51	Apricots	20	10	19.80	1.98
52	Peaches, prunes, apricots, almonds	15	10	23.80	2.38
52	Peaches and almonds	8–20	40	95.20	2.38
	Totals and average		138	248.03	1.80

Summary.

Locality	Number of orchards	Total acres	Total acre feet	Acre feet per acre
Mojave River bottom	2	21	50.13	2.39
East Mesa	8	510	598.36	1.17
West Mesa	11	265	130.84	.49
Lucerne Valley	3	68	59.36	.88
Yucaipa	4	39	65.21	1.67
San Timeteo Canyon	2	35	14.40	.41
Perris Valley	3	30	20.40	.68
Beaumont	12	172	65.55	.38
Banning	8	138	248.03	1.80
Totals and average	53	1,278	1,252.80	.98

The average amount of water applied to the 53 orchards representing a combined area of 1,278 acres giving proper weight to the area of each orchard is .98 acre-foot per acre. This summary includes orchards of all ages. The results when segregated for trees under 5 years of age and over 5 years of age are shown by Tables No. 11 and No. 12.

TABLE No. 11.

Summary for Orchards Under Five Years of Age.

Locality	Number of orchards	Total acres	Total acre feet	Acre feet per acre
Mojave River bottom	1	6	11.88	1.98
East Mesa	7	480	426.76	.89
West Mesa	6	195	59.50	.31
Lucerne Valley	3	68	59.88	.88
Yucaipa	1	10	3.60	.36
San Timeteo Canyon	0	0	0	
Perris Valley	3	30	20.40	.68
Beaumont	2	18	7.20	.40
Banning	0	0	0	
Totals and average	23	807	589.22	.73

TABLE No. 12.

Summary for Orchards Over Five Years of Age.

Locality	Number of orchards	Total acres	Total acre feet	Acre feet per acre
Mojave River bottom	1	15	38.25	2.55
East Mesa	1	30	171.60	5.72
West Mesa	5	70	71.34	1.02
Lucerne Valley	0	0	0	
Yucaipa	3	29	61.61	2.12
San Timeteo Canyon	2	35	14.40	.41
Perris Valley	0	0	0	
Beaumont	10	154	58.35	.38
Banning	8	138	248.08	1.80
Totals and averages	30	471	663.58	1.41

The average used on 23 orchards representing 807 acres of trees under 5 years is .73 acre-foot per acre and the average for 30 orchards representing 471 acres in trees over 5 years is 1.41 acre-feet per acre. This latter group includes an orchard in the river bottom at Oro Grande, tract No. 1, and the Victor Ranch on the first bench, tract No. 3, which are not representative of conditions on the mesas and for which the duty of water is excessively low. Eliminating these the average for the orchards over 5 years of age with a combined area of 426 acres is 1.07 acre-feet per acre. Most of the orchards in Victor Valley appear to have had insufficient water for vigorous growth and production.

The results for the individually owned orchards are supplemented by figures on the gross duty of water for the areas served by several irrigation systems delivering water principally for deciduous fruit trees as given by Table No. 13. The figures, except for the Banning Water Company, are from measurements. The duty for the Beaumont Land and Water Company is for 1913 and that for the Lake Hemet Water Company is an average of several seasons. The duty for the other systems is for 1916.

TABLE No. 13.

Duty of Water for Deciduous Orchards Under Irrigation Systems.

Irrigation system	Kind of trees	Acres	Rainfall in feet	Irrigation in feet	Total water in feet
Yucaipa Water Co. No. 1	Apples, cherries, etc.	2051	1.50	.58	2.08
Beaumont Land & Water Co.	Miscellaneous deciduous	1065	1.66	.12	1.78
Banning Water Co.	Miscellaneous deciduous	2700	1.10	1.47	2.57
Lake Hemet Water Co.	Deciduous and citrus	5600	1.00	1.10	2.10
Palmdale Water Co.	Pears	200	.50	.75	1.25
Little Rock Creek Irri. Dist.	Pears	1500	.60	.85	1.45
Average				.80	1.86

The Yucaipa Company delivers to orchards of all ages and the water supply has been adequate. Although the precipitation at Beaumont is high the amount given for the system is considered insufficient for the locality. The duty for the Banning Company is based on the amount of water available for use, 11 second-feet, for six months. The amount actually used may have been less. This company has a plentiful supply and it is probable that more water is used than is necessary. Most of the Hemet orchards are decidous but some are in citrus fruits. The trees at Palmdale are young and more water should be used when they become mature. Only about 200 acres of the total area given for the Little Rock district were of full bearing age in 1916 and the amount used in this district should increase in the future.

The average amount of water applied under these irrigation systems is .80 acre-foot per acre and the average total, including rainfall, is 1.86 acre-feet per acre. To give the equivalent of this latter amount in Victor Valley it would be necessary to apply 1.36 feet of irrigation water assuming an average rainfall of .5 foot per annum.

The only records of rainfall on the east mesa are for such short periods as to be of little value for comparison. However, it is believed that the east mesa, being on the average about 200 feet lower than the west mesa, has less rainfall and that the amount of water should be from 10 to 20 per cent greater than for the west mesa. It is recommended that the duty of water be estimated at 1.25 acre-feet per acre for the

west mesa and 1.50 acre-feet per acre for the east mesa. No allowance is made for loss in distribution, but neither is any account taken of the land that would be devoted to buildings and which would not require irrigation.

One miner's inch flowing continuously for a season of 200 days is equivalent to a depth of 1.25 feet on 6.40 acres, and a depth of 1.50 feet on 5.33 acres.

WATER RIGHTS.

The first irrigation ditches on Mojave River were constructed in the early seventies below and near the Lower Narrows. In a few years others were constructed on the West Fork and near the Upper Narrows. It appears that the early irrigators relied mainly on the use of the water to establish their priorities and for some of the ditches did not accompany their appropriations with the formality of filing until after the ditches had been used, while for other ditches they never filed. On the other hand, as with most streams of the arid country, many claims have been recorded which did not materialize by the construction of ditches and use of water. It is estimated from a review of the county water records that several hundred such filings have been made on the Mojave. Probably the one of most liberal conception was a promoter's claim for 1,000,000 miner's inches to be diverted from the river near Hicks by a canal to be 400 feet wide on top, 250 feet wide on the bottom, 10 feet deep, and to have a grade of 3 feet per mile, for irrigating 10 townships (230,400 acres) of land below Daggett.

The earliest claim recorded is dated April 21, 1861, and is for the entire river down to bedrock for 3 miles near the mill-site at Flat Salt Springs. This and other claims filed in the sixties were for mining purposes. The first recorded claim for an irrigation ditch that was constructed and used was for the Lane & Riley Ditch in 1872. Next came the Houlton filing on the West Fork and the Pearl filing on the main river in 1873. These are followed by the filing for the Rogers Ditch in 1876. The filings for most of the other ditches so located as to have a sufficient supply of water every year had been made by 1885.

Table No. 14 associates the filings as identified from the records and other essential data with the original and present names of the ditches, the list being in order of location downstream. Several of the older ditches were abandoned, in some cases the water right being exercised through other ditches. Others have been changed as to location of intake with the shifting of the river channel and a few have been relocated throughout.

Under an act of the legislature of 1864 and applying to San Bernardino County only, the county maintained a board of water commissioners for a number of years to administer the waters of the streams, an institution fashioned after that of the early Mormon communities in Utah. The commissioners were to "locate" ditches and to apportion the water in them annually. They annually selected a water master for each ditch to make the apportionment and the reports of the water masters to the board are a matter of record. The main activities of the commissioners related to the more populous settlements on the Santa Ana River and tributaries, but in 1879, acting on petition of residents, they gave attention to irrigation on Mojave River. On January 15th of that year they met on the banks of the river and located six ditches near the Lower Narrows, assigning to them names and numbers and alloting to them amounts as shown by the table. The basis of the numbering is not made clear and the order is probably arbitrary. The numbers are not according to location and they are not understood to represent priorities. Several other ditches were in use on other parts of the river at this time.

TABLE

Data on Ditches

Original or former name of ditch	Allotment by county water commissioners			Claim of appropriation		
	Number of ditch.	Date	Amount miner's inch.	Claimants	Date	Amount miner's inch.
Upper West Fork				Amos Houlton	May 30, '73	800
				C. A. Burcham	Jan. 27, '88	2,000
Lower West Fork				J. F. Houghton	Jan. 9, '82	10,000
				C. A. Burcham	Jan. 16, '92	10,000
Grass Valley Creek				O. A. Burcham	Jan. 6, '85	5,000
Lang				Wm. R. Lang	Mar. 18, '11	500
Hesperia				Hesperia Land & Water Co.	Aug. 13, '85	5,000
East Fork				O. A. Burcham	June 27, '83	10,000
Laughlin				Sanford C. Laughlin	Jan. 2, '09	1,500
Cole				A. W. Cole	(No filing)	
Cory				E. L. Horton and J. C. Cory.	Feb. 20, '07	1,000
Carden				H. G. Carden	May 7, '07	500
Upper Brown				Jas. Waters Jr, and Jas. Brown.	Oct. 28, '82	1,000
Lower Brown				John Brown	(No filing)	
Rogers				Samuel Rogers and Wm. Ross.	Jan. 31, '76	1,000
Allison				A. J. Spencer	Jan. 10, '80	2,000
Atwood					(No filing)	
Mill				Hallock, Congar, Clancey and Goldsworthy.	Oct. 15, '80	4,000
Hulday Pearl	2	Jan. 15, '79	100	Hulday Pearl	(No filing)	
Foote	4	Jan. 15, '79	500	Geo. E. Foote	(No filing)	
Pioneer	1	Jan. 15, '79	300	Atkinson, Lane, Swarthout and Bemis.	April 17, '85	800
Wild Goose	6	Jan. 15, '79	300	Riley, Deerow and Snodderly.	(No filing)	
A. H. Pearl				A. H. Pearl	July 25, '73	whole river
Lane & Riley	3	Jan. 15, '79	100	A. G. Lane	Oct. 22, '72	400
Snodderly & Decrow	5	Jan. 15, '79		E. Snodderly and Geo. Decrow.	(No filing)	
Bledsoe & Robinson				J. B. Bledsoe and J. D. Clark.	April 30, '83	
				Bledsoe, Clark, Robinson and Boren.	Oct. 6, '83	600
				Francis A. Haws	Dec. 15, '83	600
McNew				Jerry McNew	(No filing)	
Boren & Schneidewidt				M. J. Tiney and F. S. Schneidewidt.	Jan. 20, '95	150
Wilson				J. A. Wilson	Oct. 13, '09	500
Hartman				H. Hartman	Dec. 23, '84	1,000
Swarthout				G. M. Swarthout and J. T. Bennette.	Dec. 18, '07	800
Richardson				Richardson and Talmadge.	Jan. 16, '08	1,000
Decrow & Scoble				Durell, Decrow and Scoble.	Oct. 28, '09	1,500
Anchiniachie				J. T. Anchiniachie	Aug. 28, '06	600
Cobb				Chapman, Cobb and Chilson.	Oct. 17, '07	4,000
Stonical					(No filing)	
Harland				R. A. Harland and D. T. Chilson.	Mar. 22, '15	200
Minneola				Wm. Deterle	Sept. 28, '98	100,000
Elmholt				Mojave River Land and Water Co.	Sept. 27, '10	20,000

No. 14

In Victor Valley

Decreed rights			Present ownership			
Name under which decreed	Date	Amount miner's inch	Name of ditch	Names of owners	Area irrigated	Remarks
			Los Flores No. 1	Victor C. Smith	200	
			Los Flores No. 2	Victor C. Smith		
			Los Flores No. 3	Victor C. Smith		
			Lang	Wm. R. Lang	50	
			Hesperia	Appleton L., W. & P. Co.	310	
			Lower Deep Creek	Appleton L., W. & P. Co.	45	
			Laughlin	Laughlin & Lauffer.	95	
			Cole	A. W. Cole	30	
			Lewis	C. C. Lewis and I. B. Miller.	40	
			Carden	H. G. Carden	75	
			Upper Verde	Rancho Verde Co.	400	
			Lower Verde	Rancho Verde Co.		
Rogers	Dec. 24, '88	800	Rogers	Heirs of Samuel Rogers.	90	Hesperia L. & W. Co. vs. Rogers.
			Driscoll	Victor C. Smith	75	Allison and Atwood combined. For ore mill.
						Abandoned.
						Abandoned.
Meyer	May 18, '97	175	Bennette	J. T. Bennette	50	Bledsoe vs. Decrow.
Davidson, Bemis & Lane.	May 18, '97	230	Pioneer	Victor C. Smith	110	Bledsoe vs. Decrow. Combined, 1879.
			Downey & Robinson.	Victor C. Smith		Combined. Water used through Pioneer 1916-7.
Decrow & Van Horn.	May 18, '97	400	Decrow	Victor C. Smith	80	Bledsoe vs. Decrow.
Bledsoe & Robinson.	May 18, '97	600	Haws & Robinson.	Victor C. Smith, W. H. Robinson, P. Huerlick.	200	Bledsoe vs. Decrow.
			McNew	Carl McNew	50	
			Schneidewidt	F. Schneidewidt	25	
			Ingraham	W. W. Ingraham	80	
			Hartman	Victor C. Smith	80	
			Swarthout	George M. Swarthout.	40	Area estimated.
			Richardson	—— Richardson	80	
			Decrow & Scoble	Decrow, Durell & Scoble.	200	
			McLean	McLean	80	Area estimated.
						Abandoned.
			Stonical	—— Stonical	20	Area estimated.
			Harland	R. A. Harland	20	Area estimated.
			Daggett	B. A. Funk and T. S. Vandyke.	250	
			Yermo	Yermo Mutual Water Co.	200	Water pumped from wells.

On January 27, 1879, also on January 23, 1880, water masters were appointed for these ditches for the seasons. The report of W. H. Robinson, water master on the Pioneer Ditch (No. 1), dated March 5, 1879, is the only one recorded. It shows the water in the ditch to have been apportioned by rotation among seven users, a complete round being made every 15 days and 7 hours.

Of the ditches located in 1879 only one, the Lane & Riley (No. 3), had a filing. Afterwards in 1885 several landowners filed on water to be used through the Pioneer Ditch (No. 1). This ditch and the Foote (No. 4), later the Meyer and now the Bennette, and the Snodderly & Decrow (No. 5) are still in use. The latter two were at first on the west side of the river but were moved to the east side following a change in the river's course in 1884. The Hulday Pearl Ditch (No. 2) which was later abandoned is not to be confused with the A. H. Pearl Ditch which was combined with the Lane & Riley into the Downey & Robinson Ditch of the present time. The Wild Goose (No. 6) was combined with the Pioneer (No. 1) October 24, 1879, the contract signed by the seven water users concerned and recorded providing that the owners of Ditch No. 1 "agree to make Ditch No. 1 as many rods long as Ditch No. 6 now is." A further memorandum is attached to the record of these transactions stating that, "_____ _____ sells his right in Pioneer Ditch (No. 1) to _____ for 500 pounds of corn, $5.35 and 25 days work on the ditch." Another agreement dated January 7, 1889, provided that eight users under the Pioneer Ditch give to three landowners a one-fifth interest in the ditch for a right of way through their lands.

The original Houlton Ditch on the West Fork is said to have been abandoned and to have been in a different location from any of the ditches used at a later time for the Burcham Ranch, now Rancho Las Flores. The relation of the present West Fork ditches to the Houlton filing would be affected not so much by a change in location as by any lapse of use for 5 years or more that may have occurred.

From the best evidence available the original Brown Ditch, constructed about 1873, was the lower of the two now on Rancho Verde. The only filing by any of the original or subsequent owners of the Brown Ranch is that of Waters and Brown in 1882, which is believed to have been for the second and Upper Brown Ditch.

The Allison and the Atwood were combined as to water right into the present Driscoll Ditch (Plate V, Fig. 2). The Mill Ditch, used for a time for an ore mill at Oro Grande, was abandoned when the mill ceased to operate and was never used for irrigation. The Hesperia Ditch, now owned by the Appleton Land, Water and Power Company,

is the only one diverting water away from the lands in the immediate river bottom.

The early settlers took advantage of the locations where the surface flow of the river is constant and the later appropriators had to depend mainly on flood waters. The ditches now diverting at favorable locations are those that were constructed prior to 1886 and they include the Las Flores No. 1, Las Flores No. 2, Hesperia, Lower Deep Creek, Upper Verde, Lower Verde, Rogers, Driscoll, Bennette, Pioneer, Downey & Robinson, Decrow, Haws and Hartman. The others constructed since 1885 are flood water ditches which receive an adequate supply only during the first part of the irrigating season. Some of these on the lower part of the river receive no water in dry years. The Daggett Ditch diverts the underflow and the Yermo Ditch is supplied by pumping from wells.

The table shows the claims for the ditches to be ridiculously extravagant in amount as was usually the case under the old California law. The filings are of little significance except as they may have protected the appropriators for a reasonable time while initiating construction and carrying it to completion and except as the appropriations may relate back to the filings where the construction was prosecuted diligently. The amounts allotted to ditches by the county water commissioners in 1879 are somewhat more moderate. The rights of the ditches if determined under the present law would be based on beneficial use. No applications to divert water from Mojave River have been received by the State Water Commission since it has had jurisdiction over appropriations under the new law effective January 1, 1914. One filing for a flood water ditch near Barstow was recorded at the county seat in the manner prescribed by the old law, since the new has been in effect.

No complete adjudication of rights on Mojave River has been made and the few priorities and decreed amounts are fixed only as regards certain other ditches or as regards certain users under other ditches involved in the litigation. The Rogers Ditch was decreed a capacity of 800 miner's inches December 24, 1888, by the Superior Court and the judgment was affirmed by the Supreme Court in *Hesperia Land and Water Company* vs. *Rogers* (83 Cal. 11). The amount is extremely liberal in consideration of the area irrigated.

Bledsoe et al. vs. *Decrow et al.* (132 Cal. 312) involved, on the part of the plaintiffs: the Bledsoe, now the Haws and Robinson Ditch, and on the part of the defendants: the Pioneer, the Meyer, formerly the Foote and now the Bennette, and the Snodderly and Decrow ditches. The plaintiffs sought to be adjulged the owners of 600 miner's inches independent of any rights of the defendants, but the Superior Court on

May 18, 1879, found that the defendants had prior rights as against the plaintiffs to divert water at their respective intakes as follows: Meyer, 175 miner's inches; Davidson, Bemis and Lane, users under the Pioneer Ditch, 230 miner's inches; and Decrow and Van Horn, 400 miner's inches. The plaintiff accepted the decree to the defendants Meyer but asked for a new trial as regards the other defendants which was ordered by the court provisional on the parties being unable to agree on certain specified terms different from those of the decree. The defendants appealed from this order and the Supreme Court on March 22, 1901, affirmed the order for a new trial but gave an opinion that the lower court should not state the terms of compromise different from the rights found to belong to the several parties. As there is no further record of this case it appears that there was no second trial or compromise and that the original decision stands. The plaintiffs were decreed the water remaining to the extent of 600 miner's inches as against the defendants after satisfying the prior rights of the defendants but this case considers only a few of the ditches on the river. The rights of both the plaintiffs and the defendants are now to a large extent in one ownership.

At a later time several suits relating to water rights were filed making the Arrowhead Reservoir and Power Company, the Appleton Land, Water and Power Company, Rancho Verde Company and other riparian landowners parties, but no action has been brought on these and by stipulation of the attorneys no action is to be brought by either party unless the other be given ten days' notice.

Most of the appropriation rights for the ditches have been used long enough to become prescriptive. So far as is known the only lack of continuous use in the sense of using water when needed for a part of each year, has been confined to the flood water ditches which can not divert water in seasons of deficient supply.

Nearly all, if not all, of the ditch owners have riparian rights which under the old law had preference over appropriation rights and were not lost by nonuse. Under the present law all water not beneficially used by 1924 will then become subject to appropriation and the preference of the riparian proprietor is reduced to the opportunity to establish his right by using the water on his land before that time.

Owing to uncertain legal definition of riparian land it has not been considered advisable to undertake any exact determination of the extent of such lands. The estimate of the area here given is based on the assumption that the riparian land is limited to the smallest subdivisions that have existed at any time touching the high-water banks of the river and its tributaries and lying within the drainage.

Excepting the lands of the Appleton Land, Water and Power Company, probably few, if any, of the original units exceeded 320 acres, and some were only 160 acres. Some of the original tracts have been subdivided. Therefore it seems sufficient to assume as an average that the riparian land does not extend back from the river more than one-half mile on either side. Considering only irrigable land and land where the flow is regular enough for crops to be matured, an estimate of 20,000 acres of riparian land is given. Adding to this another 20,000 acres for the Appleton company lands, the total estimated area of riparian lands that should be taken account of is about 40,000 acres.

Table No. 14 shows the area of land claimed by the owners to be irrigated under each ditch, the total for all ditches being 3,095 acres of which 2,785 acres are in the river bottom and 310 acres on the mesa at Hesperia. In addition to the 20,000 acres of riparian land owned by the Appleton company other large holdings are estimated not to exceed as follows: Victor C. Smith 5,300 acres, of which 1,500 acres are on Rancho Las Flores, 600 acres are between the Forks and Victorville and 3,200 acres are below Victorville; Rancho Verde Company 1,500 acres; and Arrowhead Reservoir and Power Company 400 acres. The other riparian lands are distributed among numerous owners. The Appleton, Arrowhead and Verde companies control about 27,000 acres of the riparian land.

UNDERGROUND WATERS.

Victor Valley is part of a great alluvial plain sloping northward from the granite mountains of the Sierra Madre Range. The swell of the debris indicates that this portion of the desert was formed in previous geological time by the northward drainage of the San Gabriel Mountains and when much more water flowed in this direction than is now carried by Sheep Creek and the other small streams of the present. Oro Grande and Antelope washes appear to have belonged to this older drainage. In the earlier time, probably that portion of the north slope of the mountains now drained southward by Lytle and Lone Pine creeks was drained northward, the flow being turned southward later by the faulting through Cajon Pass.

The more rounded peaks and more numerous flats of the San Bernardino Mountains in contrast to the sharper outlines and deeper cut canyons resulting from long continued erosion of the San Gabriel Mountains, show the former to have been uplifted in later time than the latter.[1] The great series of faults running diagonally through the range and dividing the two groups of mountains occurred with this movement in relatively recent geological time and formed Cajon Pass.[2] Appar-

[1]United States Geological Survey, Water Supply Paper No. 219, by W. C. Mendenhall.
[2]United States Geological Survey, Bulletin 613.

ently the elevation of the San Bernardino group produced the drainage of Mojave River which has eroded its channel across the old alluvium separating what was formerly a continuous plain into the east and west mesas.

Mojave River flows through a valley .5 to 2 miles wide and from 100 to 150 feet deep between the east and west mesas as far as the Lower Narrows, and the terrace of the mesa continues on the west side of the channel as far as Hicks.

The east mesa is limited on the north by mountains and buttes and is open to the east only through the constricted pass between Granite Mountain and the San Bernardinos. The west mesa (Plate VI, Fig. 1) is of much broader extent and is only indefinitely bounded on the north by the Shadow Mountains while to the west it continues as the vast plain of Mojave Desert for many miles beyond Victor Valley which may be considered as reaching only to the San Bernardino and Los Angeles County line.

The west mesa slopes from an elevation of 4,000 feet near the foothills to 2,700 feet in a distance of 15 miles out on the plain. The slope is about 100 feet per mile west of Hesperia and it gradually becomes flatter towards the north. The east mesa is in general lower than the west mesa and it has much less slope.

The materials of these mesas, where exposed by the banks of the streams, are shown to have the character of rudely stratified stream detritus. The logs of wells show the same materials to extend throughout the plain. Some of the hills to the north of Victor Valley are of volcanic origin and consist of tuff, rhyolite, and lava.[1]

A survey was made of the wells and pumping plants to determine location, depth to water, and the extent to which pumping can be relied upon for the reclamation of the land. Levels were run to establish the elevation of the water in the wells and for the platting of hydrographic contours from which to make deductions concerning the slope and direction of movement of the underground water. The elevation of the water along lines from east to west is in general above the river on the west side and nearly level with the river on the east side. The slope of the water is less than that of the land, the difference being more marked on the west, than on the east side. In the center of the west mesa it is 15 feet per mile and to the north and northeast. On the east mesa it is to the north but it becomes nearly level over a large area. The ground water east of the river appears to have much more direct connection with the stream than that on the west side. On the east the main source is the river underflow and but minor additions are made to the basin by the foothill drainage to the southeast. The water is

[1]United States Geological Survey, Bulletin 613.

held up and forced to return to the stream above the Upper Narrows by the rocky barrier limiting Apple Valley on the north. The West Fork probably contributes to the water in the west mesa and apparently other waters move through the mesa from the foothills west of Cajon Pass in a direction towards Victorville and Oro Grande. The subterranean basin in Mirage Valley no doubt received waters percolating from the region of Sheep Creek. The Shadow Mountains and buttes arrest these waters and divert them eastward or westward from the Mirage dry lake or "Playa" (Plate VI, Fig. 2).

Numerous springs occur along the west bank of the river from a point 2 miles above, to a point 4.5 miles below, the Upper Narrows. None are found on the east bank. The water seeps from the sandy strata confined between alternating clay strata. The strongest flowing are situated at the Turner ranch below the narrows and about midway between Victorville and Oro Grande. Some of the springs have been developed by tunneling into the sandy layers from which the water outcrops and the flow is used for domestic purposes and for the irrigation of gardens. Those at the Turner ranch fill a small reservoir from which the water is taken to irrigate a field of considerable size. The several groups of springs vary in elevation but 40 feet throughout the 6.5 miles along the river bank and their positions coincide with the water plane of the mesa as shown by the wells. Those upstream and most of those downstream from the Upper Narrows are above the level of the river at that point and those at the Turner ranch, 3.5 miles below Victorville, are but little lower than those near the town while the river falls 67 feet in the same distance. The water in the test well just northwest of the narrows stands 8 feet above the water in the river at the narrows. This seems to show that the seepage water is not from the river immediately above the narrows but, if from the river, rather from some point farther upstream, or from the West Fork, by an indirect route through the mesa. Other observations indicate that the river underflow does not detour around the west side of the rock at the Upper Narrows. The artesian flow from the wells above the narrows is confined to the river bottom and it comes from strata below bedrock in the narrows. The artesian head should not be produced if the passage of the water around the narrows were not obstructed. The same conclusion is reached from the stream flow. The measurements show a loss in the West Fork from the mouth of Horsethief Creek to the Forks, about the same in the main river at the Forks and at the Upper Narrows and a gain from the upper, to the Lower Narrows.

In the event of water being impounded during a part of each season by a dam at the upper narrows, it is probable that the head produced by the stored water would reverse the movement of the seepage and

cause water to flow out of instead of into the basin above the west end of the dam. It is also possible that such a reservoir would resist the escape of seepage from the east mesa sufficiently to raise the level of the ground water and lessen the pumping lift for wells on the First Bench and the western portion of Apple Valley.

The ground water on being encountered in drilling has generally risen above the first water bearing stratum in wells piercing more than one such stratum. This artesian action is understood to have been as much as 12 feet in parts of the east mesa and as much as 20 feet in parts of the west mesa but it has not been sufficient to cause any wells outside the river bottom to flow. The water level is approximately shown by the hydrographic contours and the depth to water is represented by the difference between the topographic and hydrographic contours on the map. Theoretically the water level is above the ground surface in the artesian area.

Comparison of the elevations of the water level in 1917 with the elevation when the wells were completed in cases where the records are available from well owners and drillers shows that the water level has receded throughout Victor Valley, in most wells not to exceed 10 feet. The drop may, in part at least, be attributed to recent dry years occurring in the declining portion of the supposed cycle of precipitation. Observations have not covered a period of long enough duration to determine whether or not pumping is depleting the underground basins in excess of the average annual contribution to them. The well waters are of good quality for irrigation.

Fig. 3 shows diagrams of the logs of some of the typical deeper wells in the different parts of Victor Valley.

WELLS AND PUMPING.

The data obtained on wells is tabulated as an appendix to this report. The information on wells 302 to 333 was furnished by the United States Geological Survey. The numbering of the wells in the table corresponds to the numbering on the accompanying map. In some cases it was not practicable to obtain all of the data to make the table complete and only such information as seems to be reasonably reliable has been included. Some of the wells are owned by nonresidents who could not be reached. The depth to water was measured wherever practicable. In other cases the statement of the owner or driller was taken. The date of measurement is given only for the wells in which depth to water was measured for this investigation. The elevations of ground and water are those determined for the mapping of the hydrographic contours. In the column showing kind of pumps the terms "single deep well" and "double deep well" refer to the single and double acting plunger

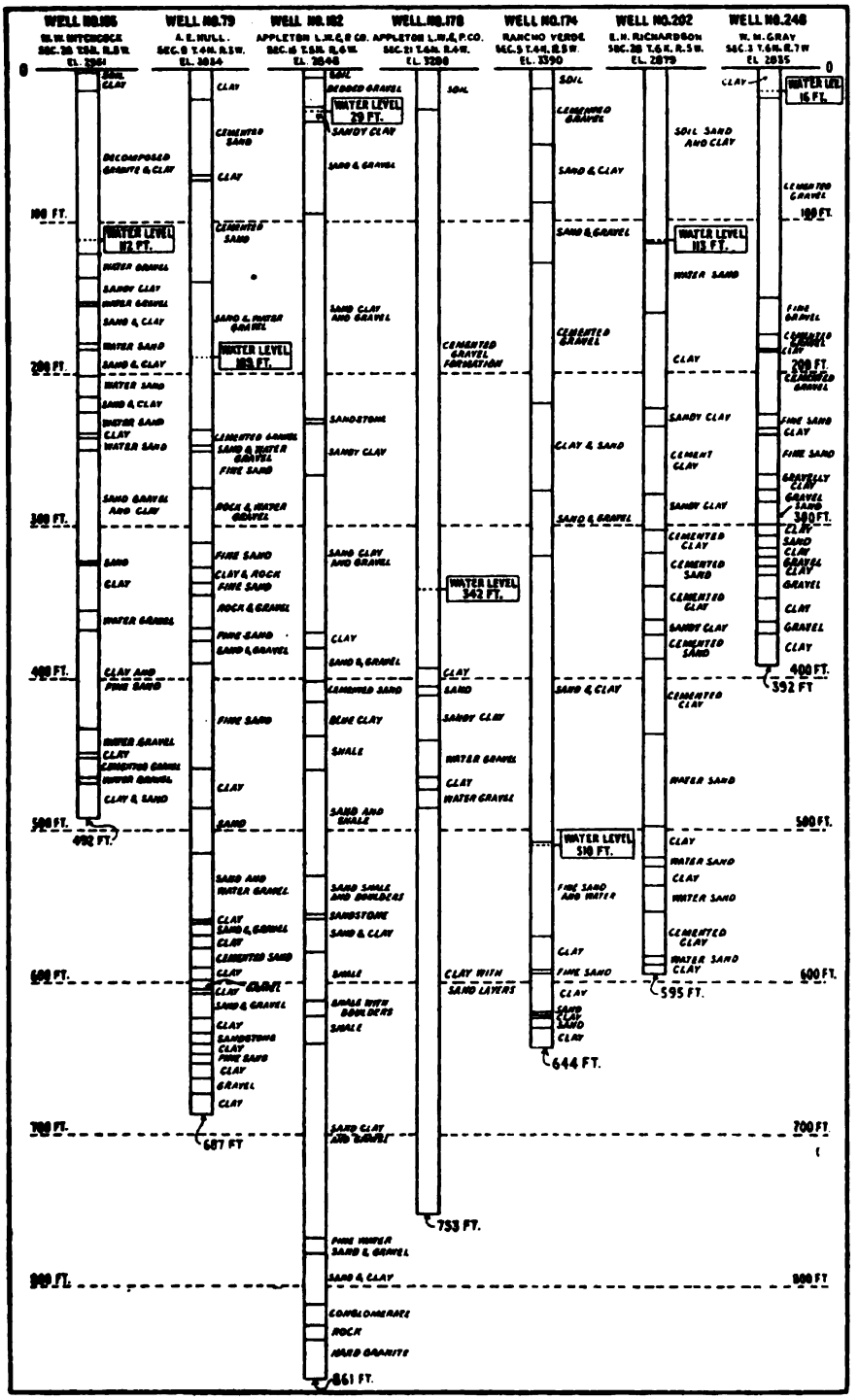


Fig. 2.—Diagrams of wells in Victor Valley.

pumps of large size developed in southern California for irrigating plants with high lifts. These pumps have become known commercially as here designated and they are distinguished from the smaller cylinder pumps used with windmills and domestic water plants.

In few cases only were the plants in operation and the discharge measured on being visited. Most of the discharges are those claimed by the owners or their representatives. Many have never been measured and they are probably overestimated. The miner's inch here used is equal to one-fiftieth part of a second-foot. Other columns in the table require no explanation.

The total number of wells between the mountains on the south and the north line of township 6 on the north and between Lucerne Valley on the east and Los Angeles County line on the west is 333. Of these 214 are drilled and steel-cased and the remainder are dug-shafts. A total of 125 wells, the most of which are drilled, are equipped with pumping machinery, the power being gasoline or oil engines with but four exceptions, and 43 wells are pumped with windmills. Although the main transmission line of the Southern Sierras Power Company crosses Victor Valley, electric power is not distributed generally to pumping plants. Thirteen wells, all located in the river bottom just above the Upper Narrows on Rancho Verde, flow.

An abundance of ground water and low lifts make pumping economical and efficient in the river bottom and on the first bench of the east mesa. This area embraces 48 pumping plants, the most of which have lifts ranging from 50 to 100 feet and discharges from 50 to 200 miner's inches.

The second or main bench of the east mesa, including the pass east of Deadman Point, has 31 pumping plants. The highest discharge for any of these is 70 miner's inches and the most are under 50 miner's inches. Excluding the plants in the pass the lifts range from 72 to 242 feet.

The west mesa includes 40 pumping plants. The lift at Hesperia is 300 feet and at one well on Baldy Mesa it is 869 feet. Such lifts are economically prohibitive for this region and but small streams of water have been pumped from these wells. The lifts are lower and the wells better near the settlement of Adelanto in Sunrise Valley and still better conditions for pumping are found in Mirage Valley. The depth to water is only about 20 feet in wells near the dry lake bed and some good producing wells are located there.

Excluding the river bottom and first bench and considering the mesa lands, it appears that the only sections in which pumping underground water can be relied upon as the sole source of supply to irrigate large solid areas are the north central portion of the east mesa, the lower

portion of Mirage Valley and possibly that in the vicinity of Adelanto. A great majority of the west mesa and a portion of the east mesa can be reclaimed only by stream flood waters, stored and conveyed by gravity.

About one-half million dollars has been invested in wells and pumping machinery in Victor Valley. In addition to the plants within the territory of the map, numerous others are pumping from wells along the lower part of the river the most being near Hicks, Barstow, Daggett and Minneola. The plain about Hinckley, 6 miles northwest of the river between Hicks and Barstow and where the underground water is no doubt in part from the river, is also the scene of pumping activity.

Included herewith are estimates of the cost of pumping intended to represent three sets of conditions found in Victor Valley. Case No. 1 is for the river bottom where the wells are comparatively shallow and good producers, the pumping lifts low, the soil sandy, the crop alfalfa, and the amount of water required high. Case No. 2 is typical of orchard irrigation in portions of Apple Valley. Here the wells are deeper, the lifts greater, the discharges less, the soil tighter and the duty of water higher. This case would apply also to a limited portion of Mirage Valley. Case No. 3 is suggested by conditions of the west mesa, particularly those of the central portion. Here the water must be used for orchards, sparingly on account of the small streams produced by the wells and the expense of pumping against high heads. Case No. 4 is a duplicate of No. 3 except that an electric motor is substituted for the engine to compare the cost of the two modes of power.

Depreciation is not counted on well and building. The percentages are selected for the several combinations of types of pumps and motive power, considering the deep well pump more durable than the centrifugal or the turbine, and the electric motor more durable than the gasoline or semi-Diesel engine. The plant efficiency is also a combination of that for the power and the pump and in fixing the percentages, preference is given slightly to motors over engines and more decidedly to deep well pumps over the types with speedily moving parts. Although deep well pumps have higher mechanical efficiency and longer life than centrifugals and turbines they generally require more expense for repairs under which is included the cost of renewing plunger leathers and the pulling of the rods. The costs of machinery on which computations of fixed charges are based are slightly less than those of the present time (1917) and they approximate the prices that obtained in 1915 which year is believed to better represent the normal.

Case No. 1.

Crop to be irrigated, alfalfa.

Depth of water on land required, 5 ft. Amount of water furnished by well, 150 mi. in. (3 sec. ft.). Season, 150 days (3,600 hrs.).

Area plant will irrigate 180 acres. Lift, 50 ft. Work done, 17 h. p.

Power required at 40 per cent efficiency, 43 h. p.

Cost of plant:

Well, 200 ft. deep, drilling at $2.00 per ft.	$400 00	
Casing, 12 in., double stove pipe, 12 gage, 180 ft. at $2.25 per ft.	405 00	
Starter, 20 ft., 3 ply, and ring	80 00	
Pit, 6 ft. x 6 ft. x 40 ft., redwood curbing at $2.00 per ft.	80 00	
		$965 00
Pump, 7 in., single stage, vertical, centrifugal, wooden frame, shafting pipe, pulley, installed complete		1,250 00
Engine, oil, 50 h. p. freight, concrete foundation, installed complete		1,850 00
Belt, 64 ft.		85 00
Building, 10 ft. x 48 ft. and derrick		500 00
Total		$4,650 00

Cost of plant per mi. in., $31.00.

Cost of plant per acre, $25.83.

Cost of operation:

Interest, $4,650.00 at 6 per cent	$279 00	
Taxes and insurance, $4,650 at 1 per cent	46 00	
Depreciation on machinery, $3,185 at 12 per cent	382 20	
		$707 70
Fuel, 40 degree (Baumé) oil, 43 h. p., 3,600 hrs., ½ gal. per h. p. hr., 19,350 gal. at $.07 per gal. delivered		1,354 50
Attendance, 150 days at $2.00 per day		300 00
Repairs, lubricating oil, etc.		50 00
Total		$2,412 20

Amount of water pumped, 150 mi. in. for 3,600 hrs., 900 acre ft.

Cost of water per acre ft., $2,68.

Cost of water per mi. in. per hr., $.0045.

Cost of water per acre per annum, $13.40.

Case No. 2.

Crop to be irrigated, apples.

Depth of water on land 1.5 ft. Amount of water furnished by well, 50 mi. in. (1 sec. ft.). Season, 150 days (3600 hrs.).

Area plant will irrigate 200 acres. Lift, 100 ft. Work done, 11.4 h. p.

Power required at 35 per cent efficiency, 32.5.

Cost of plant:

Well, 400 ft. deep, drilling at $2.00 per ft.	$800 00	
Casing, 12 in. double stove pipe, 12 gage, 380 ft. at $2.25 per ft.	855 00	
Starter, 20 ft., 3 ply, and ring	90 00	
		$1,745 00
Pump, 9½ in., 8 stage, turbine, installed complete		2,150 00
Engine, oil, 35 h. p., freight, concrete foundation, installed complete		1,400 00
Belt, 60 ft.		70 00
Building 10 ft. x 48 ft. and derrick		500 00
Total		$5,865 00

Cost of plant per mi. in., $117.30.
Cost of plant per acre, $29.32.
Cost of operation:

Interest, $5,865 at 6 per cent	$351 90	
Taxes and insurance, $5,865 at 1 per cent	58 65	
Depreciation on machinery, $3,620 at 13 per cent	470 60	
		$881 15
Fuel, 40 degree (Baumé) oil, 32.5 h. p., 3,600 hrs., ½ gal. per h. p. hr., 14,625 gal. at $.07 per gal. delivered		1,023 75
Attendance, 150 days at $2.00 per day		300 00
Repairs, lubricating oil, etc.		50 00
Total		$2,254 90

Amount of water pumped, 50 mi. in. for 3,600 hrs., 300 acre ft.
Cost of water per acre ft., $7.52.
Cost of water per mi. in. per hr., $.0125.
Cost of water per acre per annum, $11.27.

Case No. 3.

Crop to be irrigated, apples.
Depth of water on land, 1.25 ft. Amount of water furnished by well, 25 mi. in. (.5 sec. ft.). Season, 150 days (3,600 hrs.)
Area plant will irrigate 120 acres. Lift, 250 ft. Work done, 14.2 h. p.
Power required at 50 per cent efficiency, 28.4 h. p.
Cost of plant:

Well, 500 ft. deep, drilling at $2.00 per ft.	$1,000 00	
Casing, 12 in., double stove pipe, 12 gage, 480 ft. at $2.25 per ft.	1,080 00	
Starter, 20 ft., 8 ply, and ring	90 00	
		$2,170 00
Pump, double acting, deep well, plunger, 20 h. p. 8 in. cyl., 56 in. double stroke, 20 strokes per min., concrete foundation, derrick and hoist, installed complete		2,400 00
Engine, oil, 30 h. p., concrete foundation, installed complete, including freight		1,250 00
Belt, 60 ft.		50 00
Building, 10 ft. x 48 ft.		400 00
Total		$6,270 00

Cost of plant per mi. in., $250.80.
Cost of plant per acre, $52.25.
Cost of operation:

Interest, $6,270 at 6 per cent	$376 20	
Taxes and insurance, $6,270 at 1 per cent	62 70	
Depreciation on machinery, $3,700 at 10 per cent	370 00	
		$808 90
Fuel, 40 degree (Baumé) oil, 28.4 h. p., 3,600 hrs., ½ gal. per h. p. hr., 12,780 gal. at $.07 per gal. delivered		894 60
Attendance, 150 days at $1.50 per day		225 00
Repairs, lubricating oil, etc.		100 00
Total		$2,028 50

Amount of water pumped, 25 mi. in. for 3,600 hrs., 150 acre feet.
Cost of water per acre foot, $13.52.
Cost of water per mi. in. per hr., $.0225.
Cost of water per acre per annum, $16.90.

Case No. 4.

Crop to be irrigated, apples.

Depth of water on land 1.25 ft. Amount of water furnished by well, 25 mi. in. (.5 sec. ft.). Season, 150 days (3,600 hrs.).

Area plant will irrigate, 120 acres. Lift, 250 ft. Work done, 14.2 h. p.

Power required at 55 per cent efficiency, 25.8 h. p.

Cost of plant:

Well, 500 ft. deep, drilling at $2.00 per ft.	$1,000 00	
Casing, 12 in., double stove pipe, 12 gage, 480 ft. at $2.25 per ft.	1,080 00	
Starter, 20 ft., 3 ply, and ring	90 00	
		$2,170 00
Pump, double acting, deep well, plunger, 20 h. p., 8 in. cyl., 56 in. double stroke, 20 strokes per min., concrete foundation, derrick and hoist, installed complete		2,400 00
Motor, 30 h. p., induction, 550 volt, 60 cycle, 3 phase, 1,800 r. p. m., concrete foundation, installed complete, including freight		520 00
Belt, 60 ft.		50 00
Building, 10 ft. x 48 ft.		400 00
Total		$5,540 00

Cost of plant per mi. in., $221.60.

Cost of plant per acre, $46.18.

Cost of operation:

Interest, $5,540 at 6 per cent	$332 40	
Taxes and insurance, $5,540 at 1 per cent	55 40	
Depreciation on machinery, $2,970 at 8 per cent	237 60	
		$625 40
Electrical power 19.25 k.w. (25.8 h.p.) 3,600 hrs., 69,300 k.w. hrs., at $.0175 per k.w. hr.		1,212 75
Attendance, 150 days at $1.00 per day		150 00
Repairs and lubricating oil		75 00
Total		$2,063 15

Amount of water pumped, 25 mi. in. for 3,600 hrs., 150 acre ft.

Cost of water per acre ft., $13.74.

Cost of water per mi. in. per hr., $.0229.

Cost of water per acre per annum, $17.19.

For orchard irrigation, especially with expensive water as under cases No. 3 and No. 4, it would be economical and desirable to use concrete pipe underground to convey and distribute the water to the furrows and trees. Such a system for a 10 acre tract is estimated to cost as follows:

630 ft. of 8 in. concrete pipe at $.18 per ft. laid	$113 40
21 stands, 30 ft. apart, with iron valves at $2.00 each	42 00
1 gate basin with iron slide gate	8 00
	$163 40

Cost per acre, $16.34.

STREAM DISCHARGE.

The mountain watershed of Mojave River has an area of 217 square miles of which 142 square miles are drained by Deep Creek or the East Fork and 75 square miles are drained by the West Fork. The watershed varies from an elevation of 8,000 feet at its highest point to 3,000 feet at the Forks where the entire drainage is brought together in the

main river. The northern slopes (Plate III, Fig. 1) of the Sierra Madre Range receive less precipitation than the southern slopes but they are less steep, less subject to direct rays of the sun, better timbered and they hold the snows longer and have slower runoff in proportion to precipitation than southern slopes.

The comprehensive metereological observations made throughout the watershed by the Arrowhead Reservoir and Power Company for over 20 years show the precipitation to vary from about 15 inches at the Forks to about 50 inches near the summit, the maximum occurring in the flats situated just north of the crest of the range, and flanked by peaks. The precipitation falls off rapidly towards the desert on the northeast. The more elevated portions of the watershed are in heavy timber of pine and fir without much undergrowth and the lower portions are covered with thick brush. Table No. 14 shows the areas drained by the branches grouped according to the reservoir sites into which they are tributary. The drainage of Deep Creek below the upper storage works can be made tributary to the Forks site by diversion.

TABLE No. 15.

Mountain Drainage Areas of Mojave River.

	Square miles	Square miles	Square miles
Deep Creek (East Fork).			
Above Little Bear Valley reservoir and tunnel—			
Little Bear Creek	6.64		
Hooks, Fern, Shake, Cedar and Sheep creeks	3.61		
Deep Creek	16.10		
Crab Creek	3.70		
Holbrook Creek and tributaries	33.76		
Cox Creek	9.89		
Grass Valley Creek[1]	2.72		
Total, Little Bear Valley reservoir		75.92	
Below Little Bear Valley reservoir and tunnel		65.88	
Total, Deep Creek			141.80
West Fork.			
Above dam site No. 2—			
East Fork of West Fork	18.82		
West Fork of West Fork	11.05		
Between dam sites Nos. 2 and 3	4.95		
Total, reservoir sites No. 2 and No. 3		34.82	
Below dam site No. 2 and Grass Valley dam site		39.96	
Total, West Fork (Forks reservoir site)			74.78
Total, Mojave River			216.58

[1]Naturally tributary to West Fork.

An examination of the precipitation records for southern California suggests the selection of a period of about 17 years as a proper one on which to base the average runoff. Tables No. 16 to No. 20 show the precipitation at several stations; the first for 65 seasons at San Diego, the longest record in southern California; the next for 45 seasons at San Bernardino, the second longest record, and the others for Glen Ranch, Bear Valley Dam and Gate House, the latter being at Little Bear Valley Dam, and the only one in the Mojave River watershed. The table for San Diego shows the average for periods of different lengths terminating with 1914-15, also the ratios of these averages to the average for the longest period. It is noticed that 17 seasons must be included to obtain a period terminating with 1914-15 to give an average equal to the average for the longest period.

The tables for the other stations show the ratios of averages for the different periods to the average for the longest period equated to the longer 65 season record at San Diego. The average for the last 17 seasons at the several stations agree remarkably well and it seems that this represents a cycle from which safe deductions of runoff can be made. However, from a study of the precipitation records of this immediate late period and from common knowledge of several seasons of low flood discharges about this time, it seems advisable, in order to consider the most unfavorable conditions which may arise, to extend the period back one additional season to include the low seasonal discharge for 1897-98, making the period 18 seasons.

TABLE No. 16.

Precipitation at San Diego.

Elevation, 93 feet.

Season	Precipitation, inches	Period	Average precipitation for period, inches	Ratio to 65 season average, per cent	Number of seasons in period
1850-51	8.41	1850-1915	9.70	100.00	65
1851-52	9.48	1851-1915	9.72	100.21	64
1852-53	11.08	1852-1915	9.72	100.21	63
1853-54	9.77	1853-1915	9.70	100.00	62
1854-55	13.56	1854-1915	9.70	100.00	61
1855-56	9.89	1855-1915	9.64	99.37	60
1856-57	4.76	1856-1915	9.63	99.27	59
1857-58	7.54	1857-1915	9.72	100.21	58
1858-59	6.61	1858-1915	9.76	100.62	57
1859-60	6.58	1859-1915	9.81	101.13	56
1860-61	7.90	1860-1915	9.87	101.75	55
1861-62	15.64	1861-1915	9.90	102.06	54
1862-63	8.87	1862-1915	9.80	101.03	53
1863-64	5.14	1863-1915	9.91	102.16	52
1864-65	8.45	1864-1915	10.00	103.09	51
1865-66	12.82	1865-1915	10.04	103.51	50
1866-67	13.73	1866-1915	9.98	102.89	49

TABLE No. 16—Continued.

Precipitation at San Diego.

Season	Precipitation, inches	Period	Average precipitation for period, inches	Ratio to 65 season average, per cent	Number of seasons in period
1867–68	11.23	1867–1915	9.90	102.06	48
1868–69	11.66	1868–1915	9.87	101.75	47
1869–70	5.48	1869–1915	9.83	101.34	46
1870–71	5.17	1870–1915	9.93	102.37	45
1871–72	7.18	1871–1915	10.04	103.51	44
1872–73	6.50	1872–1915	10.11	104.23	43
1873–74	16.88	1873–1915	10.19	105.05	42
1874–75	5.73	1874–1915	10.02	103.30	41
1875–76	10.11	1875–1915	10.14	104.54	40
1876–77	3.75	1876–1915	10.13	104.43	39
1877–78	16.10	1877–1915	10.30	106.18	38
1878–79	7.88	1878–1915	10.15	104.64	37
1879–80	14.36	1879–1915	10.21	105.25	36
1880–81	9.66	1880–1915	10.09	104.02	35
1881–82	9.51	1881–1915	10.11	104.22	34
1882–83	4.92	1882–1915	10.12	104.33	33
1883–84	25.97	1883–1915	10.29	106.06	32
1884–85	8.67	1884–1915	9.78	100.82	31
1885–86	16.96	1885–1915	9.82	101.24	30
1886–87	8.32	1886–1915	9.57	98.66	29
1887–88	9.82	1887–1915	9.62	99.17	28
1888–89	11.02	1888–1915	9.61	99.07	27
1889–90	15.02	1889–1915	9.55	98.45	26
1890–91	10.47	1890–1915	9.33	96.18	25
1891–92	8.70	1891–1915	9.29	95.77	24
1892–93	9.26	1892–1915	9.31	95.88	23
1893–94	4.97	1893–1915	9.32	96.08	22
1894–95	11.90	1894–1915	9.52	98.14	21
1895–96	6.21	1895–1915	9.40	96.91	20
1896–97	11.78	1896–1915	9.57	98.66	19
1897–98	4.99	1897–1915	9.45	97.42	18
1898–99	5.24	1898–1915	9.71	100.10	17
1899–00	5.97	1899–1915	9.99	102.99	16
1900–01	10.45	1900–1915	10.26	105.77	15
1901–02	6.17	1901–1915	10.24	105.57	14
1902–03	11.76	1902–1915	10.56	108.87	13
1903–04	4.40	1903–1915	10.46	107.83	12
1904–05	14.32	1904–1915	11.01	113.50	11
1905–06	14.68	1905–1915	10.68	110.10	10
1906–07	10.62	1906–1915	10.23	105.46	9
1907–08	8.55	1907–1915	10.19	105.05	8
1908–09	10.23	1908–1915	10.42	107.42	7
1909–10	9.79	1909–1915	10.45	107.73	6
1910–11	11.99	1910–1915	10.58	109.07	5
1911–12	10.72	1911–1915	10.23	105.46	4
1912–13	5.97	1912–1915	10.07	103.81	3
1913–14	9.83	1913–1915	12.12	124.95	2
1914–15	14.41	1914–1915	14.41	148.55	1

TABLE No. 17.

Precipitation at San Bernardino.

Elevation, 1,054 feet.

Season	Precipitation, inches	Period	Average precipitation for period, inches	Ratio to 45 season average, per cent	Ratio to equated 65 season average, per cent	Number of seasons in period
1870–71	13.94	1870–1915	16.01	100.00	102.37	45
1871–72	8.98	1871–1915	16.05	100.25	102.62	44
1872–73	15.10—	1872–1915	16.22	101.31	103.71	43
1873–74	23.81	1873–1915	16.24	101.43	103.84	42
1874–75	13.65	1874–1915	16.06	100.31	102.69	41
1875–76	19.90	1875–1915	16.12	100.69	103.07	40
1876–77	9.52	1876–1915	16.02	100.06	102.43	39
1877–78	20.33	1877–1915	16.19	101.12	103.52	38
1878–79	11.54	1878–1915	16.08	100.43	102.82	37
1879–80	20.36	1879–1915	16.21	101.24	103.64	36
1880–81	13.50	1880–1915	16.09	100.50	102.88	35
1881–82	11.54	1881–1915	16.17	100.99	103.39	34
1882–83	9.17	1882–1915	16.31	101.87	102.80	33
1883–84	37.51	1883–1915	16.53	103.25	105.69	32
1884–85	10.81	1884–1915	15.85	99.00	101.34	31
1885–86	21.93	1885–1915	16.02	100.06	102.63	30
1886–87	14.50	1886–1915	15.82	98.81	101.15	29
1887–88	17.76	1887–1915	15.86	99.06	101.41	28
1888–89	20.97	1888–1915	15.79	98.62	100.96	27
1889–90	25.45	1889–1915	15.68	97.94	100.02	26
1890–91	18.08	1890–1915	15.20	94.94	97.19	25
1891–92	14.35	1891–1915	15.08	94.19	96.42	24
1892–93	19.82	1892–1915	15.11	94.37	96.61	23
1893–94	8.13	1893–1915	14.90	93.06	95.27	22
1894–95	20.98	1894–1915	15.22	95.06	97.32	21
1895–96	8.11	1895–1915	14.94	93.31	95.52	20
1896–97	16.74	1896–1915	15.29	95.50	97.76	19
1897–98	8.24	1897–1915	15.21	95.03	97.25	18
1898–99	7.49	1898–1915	15.62	97.56	99.87	17
1899–00	8.64	1899–1915	16.13	100.74	103.13	16
1900–01	17.96	1900–1915	16.63	103.87	106.33	15
1901–02	11.15	1901–1915	16.58	103.56	106.01	14
1902–03	17.42	1902–1915	16.99	106.12	108.63	13
1903–04	9.37	1903–1915	16.96	105.93	108.44	12
1904–05	20.78	1904–1915	17.65	110.24	112.85	11
1905–06	19.88	1905–1915	17.34	108.31	110.87	10
1906–07	23.17	1906–1915	17.06	106.56	109.08	9
1907–08	15.62	1907–1915	16.29	101.12	104.16	8
1908–09	17.36	1908–1915	16.39	102.37	104.80	7
1909–10	15.02	1909–1915	16.23	101.37	103.77	6
1910–11	16.34	1910–1915	16.47	102.87	103.06	5
1911–12	13.84	1911–1915	16.50	103.06	105.50	4
1912–13	11.08	1912–1915	17.39	108.62	111.19	3
1913–14	21.45	1913–1915	20.55	128.36	131.39	2
1914–15	19.64	1914–1915	19.64	122.67	125.58	1

TABLE No. 18.

Precipitation at Glen Ranch, San Bernardino Mountains.

Elevation, 3,256 feet.

Season	Precipitation, inches	Period	Average precipitation for period, inches	Ratio to 15 season average, per cent	Ratio to equated 65 season average, per cent	Number of seasons in period
1900-01	29.27	1900-1915	33.76	100.00	106.33	15
1901-02	15.00	1901-1915	34.08	100.94	107.33	14
1902-03	29.75	1902-1915	35.55	105.30	111.97	13
1903-04	18.53	1903-1915	36.04	106.75	113.51	12
1904-05	38.41	1904-1915	37.63	111.46	118.51	11
1905-06	37.63	1905-1915	37.55	111.22	118.26	10
1906-07	49.69	1906-1915	37.54	111.19	118.23	9
1907-08	25.95	1907-1915	36.02	106.69	113.44	8
1908-09	33.88	1908-1915	37.46	110.96	117.98	7
1909-10	34.67	1909-1915	38.06	112.73	119.87	6
1910-11	45.86	1910-1915	38.75	114.78	122.05	5
1911-12	36.45	1911-1915	36.95	109.44	116.37	4
1912-13	20.13	1912-1915	37.12	109.95	116.91	3
1913-14	53.61	1913-1915	45.62	135.13	143.68	2
1914-15	37.63	1914-1915	37.63	111.46	118.51	1

TABLE No. 19.

Precipitation at Bear Valley Dam.

Elevation, 6,500 feet.

Season	Precipitation, inches	Period	Average precipitation for period, inches	Ratio to 23 season average, per cent	Ratio to equated 65 season average, per cent	Number of seasons in period
1892-93	44.31	1892-1915	34.37	100.00	96.35	23
1893-94	24.86	1893-1915	33.92	98.69	95.09	22
1894-95	50.29	1894-1915	34.35	99.94	96.30	21
1895-96	11.29	1895-1915	33.56	97.64	94.83	20
1896-97	33.25	1896-1915	34.73	101.04	97.35	19
1897-98	20.22	1897-1915	34.81	101.28	97.59	18
1898-99	13.93	1898-1915	35.67	103.78	100.00	17
1899-00	20.47	1899-1915	37.03	107.74	103.81	16
1900-01	31.52	1900-1915	38.13	110.93	106.88	15
1901-02	26.68	1901-1915	38.61	112.33	108.23	14
1902-03	40.42	1902-1915	39.52	114.98	110.79	13
1903-04	25.15	1903-1915	39.45	114.78	110.60	12
1904-05	44.36	1904-1915	40.75	118.56	114.24	11
1905-06	48.25	1905-1915	40.39	117.51	113.23	10
1906-07	48.38	1906-1915	39.51	114.95	110.26	9
1907-08	30.12	1907-1915	38.41	111.75	107.68	8
1908-09	38.20	1908-1915	39.59	115.18	110.84	7
1909-10	34.15	1909-1915	39.82	115.85	111.63	6
1910-11	49.21	1910-1915	40.96	119.17	114.88	5
1911-12	25.60	1911-1915	38.89	113.15	109.02	4
1912-13	22.00	1912-1915	43.32	126.04	121.45	3
1913-14	53.05	1913-1915	53.90	156.82	151.11	2
1914-15	54.98	1914-1915	54.98	159.82	154.00	1

TABLE No. 20.

Precipitation at Gate House, Little Bear Valley.

Elevation, 5,200 feet.

Season	Precipitation, inches	Period	Average precipitation for period, inches	Ratio to 22 season average, per cent	Ratio to equated 65 season average, per cent	Number of seasons in period
1893-94	23.60	1893-1915	31.36	100.00	96.79	22
1894-95	48.66	1894-1915	31.73	101.18	97.93	21
1895-96	13.84	1895-1915	30.88	98.46	95.30	20
1896-97	33.65	1896-1915	31.78	101.34	98.09	19
1897-98	19.40	1897-1915	31.68	101.02	97.78	18
1898-99	13.66	1898-1915	32.40	103.31	100.00	17
1899-00	22.77	1899-1915	33.57	102.05	98.78	16
1900-01	36.73	1900-1915	34.09	108.71	105.22	15
1901-02	20.70	1901-1915	34.12	108.80	105.31	14
1902-03	30.13	1902-1915	35.15	112.08	108.48	13
1903-04	24.32	1903-1915	35.57	113.42	109.78	12
1904-05	36.68	1904-1915	36.59	116.68	112.94	11
1905-06	42.95	1905-1915	36.59	116.68	112.94	10
1906-07	57.48	1906-1915	35.88	114.41	110.74	9
1907-08	26.29	1907-1915	33.18	105.80	102.41	8
1908-09	40.66	1908-1915	34.16	109.28	105.77	7
1909-10	33.23	1909-1915	33.06	105.42	102.04	6
1910-11	44.63	1910-1915	33.05	105.38	102.00	5
1911-12	23.18	1911-1915	30.16	96.17	93.06	4
1912-13	21.99	1912-1915	32.48	103.57	100.25	3
1913-14	43.88	1913-1915	37.73	120.31	116.46	2
1914-15	31.59	1914-1915	31.59	100.73	97.50	1

Several sets of measurements have been used to determine the mean annual discharge of Mojave River in the preparation of this report. The Arrowhead Reservoir and Power Company measured the streams in the upper watershed now tributary or to be tributary to Little Bear Valley reservoir beginning with 1891-2, except the seasons 1900-1 to 1903-4, inclusive, also the East and West Forks at the Forks (Plate II, Fig. 2) and the main river at the Lower Narrows (Plate V, Fig. 2) continuously beginning with 1905-6. The United States Geological Survey maintained a gaging station on the river at the Upper Narrows (Plate V, Fig. 1) 1899-1900 to 1905-6, inclusive, and the Mojave Water and Power Company continued the measurements to and including 1913-14, also measured the East and West Forks at the Forks 1906-7 to 1913-14, inclusive. Thus both the Arrowhead and Mojave companies gaged the flow at the Forks from 1908-9 to 1913-14, inclusive, so that these measurements, being for the same seasons at the same point are directly comparable. The several measurements were compared and correlated in the following manner: All apparent conflicts between the several series were subjected to detailed study, the computations being

checked from the original daily records. It was found that the only material differences occurred in the records of the heavier winter floods. In one instance of considerable conflict, the Forks records for 1911-12, regarding which no other method of weighing the value of the records suggested itself, recourse was had to the precipitation record which definitely indicated that preference should be given the Arrowhead company's measurement.

In general, the precipitation records were not of as much value in checking the discharge as the comparison of the discharge measurements themselves. A study of the precipitation is, however, not without interest. In only two seasons were any errors of consequence found in the Forks measurements of the Arrowhead company. Both appeared to have occurred in plotting the larger flood records and to be due to infrequency of measurements, probably caused by the difficulty of obtaining them during the period of excessive flow. In only one instance was the error of enough magnitude to affect appreciably the average for a period of years. This was for the heavy flood of 1909-10 where the measurement of Deep Creek was 130,000 acre-feet while that of the Mojave Water and Power Company was 76,000 acre-feet. Fortunately measurements were made at both the Upper and Lower Narrows for this season. By plotting these with allowance for the difference in time of the peak of the flood at the different points and with an interpolation of the curve of the declining flood as obtained from the more frequent measurements at the Narrows during the same time a corrected curve was obtained for the Forks which reduced the Arrowhead company's measurement about 31,000, but still left a difference of about 23,000 acre-feet between the measurement of this company and that of the Mojave company. As these could not be further reconciled an average of them was taken. The same method was applied for the seasons 1908-9 to 1913-14, inclusive, during which the two measurements were made at the Forks. The Arrowhead company made the only measurements at the Forks for 1906-7 and 1907-8. The records agree so well with those of the Mojave company at the Upper Narrows that they are assumed to be correct.

A marked discrepancy occurs for the season 1905-6 between the measurements of the Arrowhead company at the Forks and those of the Geological Survey at the Upper Narrows as shown by Table No. 21. The published government records[1] are incomplete for the latter part of the season and the data were supplied by the Mojave Water and Power Company.

[1]United States Geological Survey. Water Supply Paper No. 300.

TABLE No. 21.

Discharge of Mojave River at Forks and Upper and Lower Narrows—1905-1906.

Month	Discharge at Forks (A. R. & P. Co.) Acre feet	Discharge at Upper Narrows (U. S. G. S.) Acre feet	Discharge at Lower Narrows (A. R. & P. Co.) Acre feet
July	449	1,986	1,318
August	82	1,943	1,602
September	43	2,380	1,659
October	102	2,859	2,383
November	360	3,808	2,761
December	659	4,120	2,841
January	3,708	4,205	2,988
February	4,876	3,637	2,498
March	84,406	126,153	56,790
April	21,771	23,766	17,758
May	12,994	6,800	8,357
June	6,305	3,909	3,135
Season	135,220	185,596	104,970

The Forks measurement for this season is approximately 135,000 acre-feet while that at the Upper Narrows is approximately 185,000 acre-feet. This increase is too large to be explained as inflow from the underground basin above the Narrows or as local runoff from the valley below the Forks. The flow at the Lower Narrows for this season was measured by the Arrowhead company to be approximately 104,000 acre-feet. The records for this season at the three points of measurement show reasonable agreement except for the month of March. The records for this month at the Forks and Lower Narrows are within the limits of what might be expected as difference between these points. The flow recorded for the Upper Narrows is manifestly incorrect if the other records are relied upon. It was therefore decided to regard the Forks record as being correct.

Disregarding 1905-6, and taking the average for 1906-7 to 1913-14, inclusive, as shown by Table No. 22, the average for these 7 years at the Forks varies less than 2 per cent from the average for the same period at the Upper Narrows.

TABLE No. 22.

Discharge of Mojave River at Forks and Upper Narrows.

Season	East Fork at Forks (Acre feet)	West Fork at Forks (Acre feet)	Mojave River at Forks (Acre feet)	Mojave River at Upper Narrows (Acre feet)	Per cent of discharge at Forks to discharge at Upper Narrows
1905-06	87,633	47,587	135,220	185,596	73.2
1906-07	136,052	118,265	254,317	259,906	98.2
1907-08	40,920	19,856	60,776	56,057	108.1
1908-09	54,257	35,483	89,740	97,781	91.8
1909-10	87,656	48,049	135,705	118,084	114.8
1910-11	86,627	61,311	147,938	135,903	108.9
1911-12	29,087	17,927	46,964	50,519	93.2
1912-13	14,900	11,460	26,360	35,297	74.6
1913-14	105,130	64,805	----------	----------	----------
1914-15	77,331	45,305	----------	----------	----------

In general, there is a loss from the Forks to the Upper Narrows in years of heavy flood and a gain in years of relatively small flood. This may be explained on the theory that water in this part of the river is lost from the surface flow to the underflow in the heavy floods and returned by the charged gravels to the surface stream above the Narrows in seasons of light discharge. It appears from the measurements that practically all of the water which enters the underground basin below the Forks is re-collected above the Narrows and flows out through them. The observations on underground water serve to confirm this belief.

The close relation shown to exist between the flow at the Forks and that at the Upper Narrows suggests an interpolation of discharge for 1899-1900 to 1904-5, inclusive, during which period no gagings were made at the Forks. Table No. 22 shows the relation between the discharge at the Forks and that at the Upper Narrows from 1905-6 to 1912-13, inclusive.

From these percentages and from the recorded discharges at the Upper Narrows from 1899-1900 to 1904-5, inclusive, the probable percentage of discharge at the Forks to that at the Upper Narrows for each season was obtained and used to compute discharges at the Forks. These results vary less than 5 per cent from the measurements at the Upper Narrows by the Geological Survey.

A report of J. B. Lippincott gives some discharges interpolated from the ratio of flow at the Forks to that of the upper tributaries for seasons where the records are available for comparison. Table No. 23 shows these interpolated results and those based on the flow at the Upper Narrows, although obtained in widely different manner, to be in reasonably close agreement. There are no complete measurements for the Forks or

either the Upper or Lower Narrows for 1897-8 and 1898-9 and the interpolated values deduced by Mr. Lippincott are assumed to be correct.

TABLE No. 23.

Interpolated Discharge of Mojave River.

Season	Discharge at Forks interpolated from discharge of upper tributaries (Acre feet)	Discharge at Forks interpolated from discharge at Upper Narrows (Acre feet)
1897-1898	27,040	27,040
1898-1899	7,710	13,886
1899-1900	20,000	18,132
1900-1901	108,100	96,596
1901-1902	33,610	33,789
1902-1903	111,800	107,315
1903-1904	35,210	28,232
1904-1905	108,294	95,016

In this manner Table No. 24 of discharges of Mojave River at the Forks has been compiled for the 18 seasons 1897-8 to 1914-15, inclusive. The average annual discharge of the river where it enters the Victor Valley basin is shown to be approximately 90,000 acre-feet.

TABLE No. 24.

Discharge of Mojave River at Forks—1897-1915, Inclusive.

Season	Discharge (Acre feet)
1897-1898	27,040
1898-1899	13,878
1899-1900	18,132
1900-1901	96,596
1901-1902	33,789
1902-1903	107,315
1903-1904	28,232
1904-1905	95,016
1905-1906	135,220
1906-1907	254,317
1907-1908	60,776
1908-1909	69,740
1909-1910	135,705
1910-1911	147,988
1911-1912	46,964
1912-1913	26,360
1913-1914	169,985
1914-1915	122,636
Average	89,416

FORKS RESERVOIR SITE.

The reservoir site on the West Fork of Mojave River just above the Forks may be designated West Fork reservoir site No. 1, or as it is generally know, the Forks reservoir site. The land in this basin, or nearly all of it including the dam site, is controlled by the Arrowhead Reservoir and Power Company. It was the original plan of the Mojave River Irrigation District to acquire and develop this site to impound the flood discharge of the West Fork and to store, by diversion, that in the lower part of the East Fork and to convey the water by gravity to the east mesa. The district, however, did not make known definite design, if any was decided upon, for the imporvement of the site.

The Arrowhead company has proposed a dam at the Fork site (Plate IV, Fig. 2) 150 feet high which would give a capacity of 102,000 acre-feet for storing both East and West Fork flood waters. Borings made by the company at the dam site show bedrock to be at a maximum depth of 18 feet below stream bed. The natural rim of the basin at one point is only 110 feet above the stream channel at the dam site and the plans include the necesary raising of this bank 50 feet to give the desired capacity. The bank is here merely a narrow remnant of detrital deposit between the channel of the West Fork and the channel of the main river at a lower elevation than the West Fork. The peculiar topography of this locality can be best understood by reference to the map. The only foundation for a dam to raise the bank, as shown by excavations made by the company, is a layer of hardpan at a depth of 75 feet below the crest of the rim.

Moderate leakage, provided the water reappeared as surface flow in the river, might not be a sufficient reason for condemning the site, for the water lost would help satisfy the owners of riparian lands and the appropriators on the stream below, but excessive leakage would impair the value of the reservoir. Robert T. Hill reported to the commission on the geology of the site as follows:

"The Forks reservoir site is an elongated basin which has been developed by erosion at the junction of the north side of the San Bernardino Range and the southern margin of the so-called Mojave Desert. It is triangular in shape and about five miles long, in a northeast-southwest direction, and about two miles in width at its widest place. It is bordered on the southeast and southwest sides by the high, and somewhat precipitous north front of the San Bernardino Range, and on the north by the even topped escarpment of the south side of the Mojave plain, which slopes away therefrom to the northeast. The floor of this basin, which is some 250 feet beneath the summit of this escarpment, shows several old levels and terraces of alluvial material,

below which the river has cut to its present level close to the northern wall.

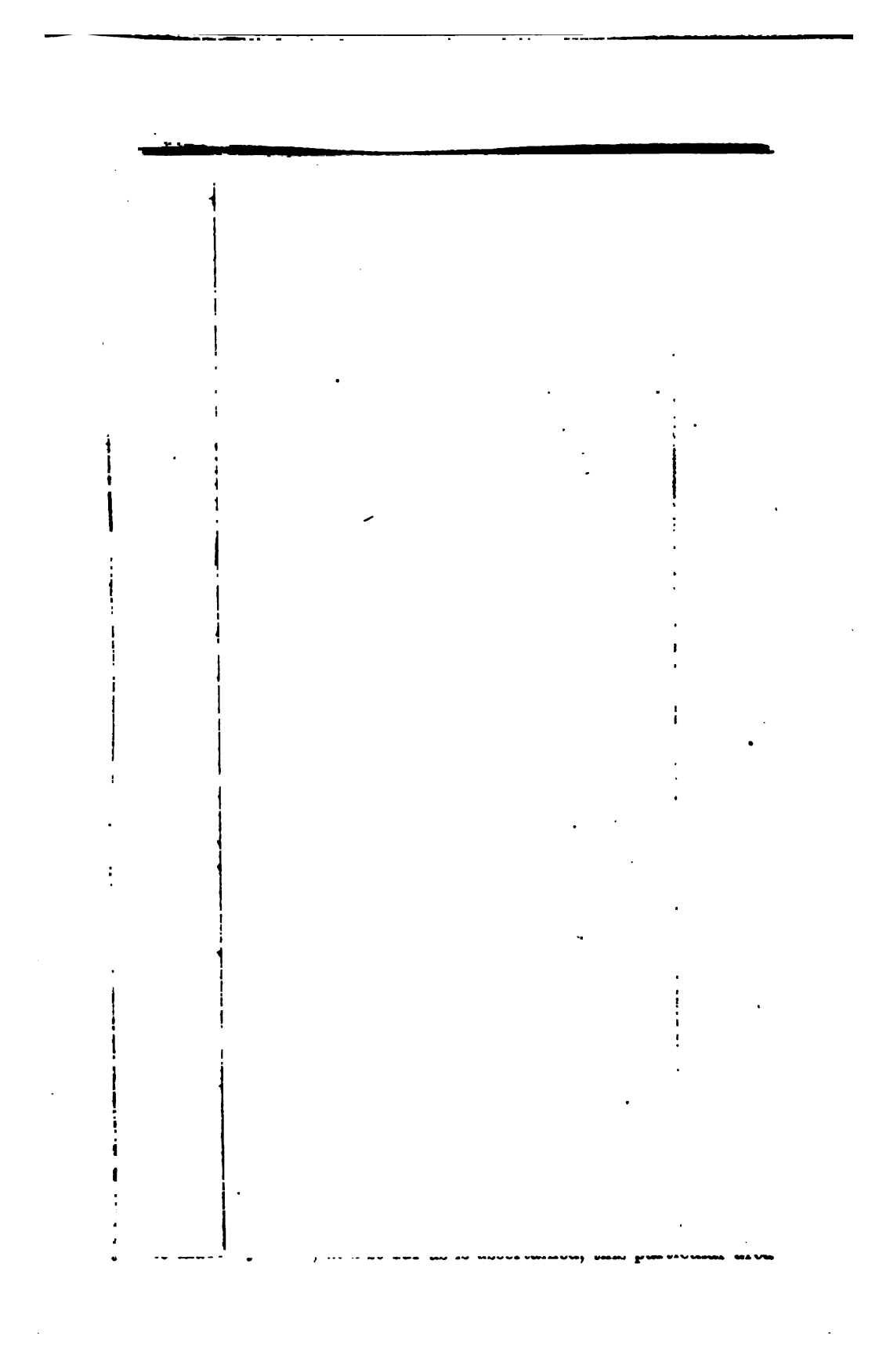
"The northeast end of the basin is closed by a natural dam which has only recently in geological time been cut through by a deep gorge at its southern end through which the river now finds an outlet. The eastern end of this dam is a low conical granitic peak, which sets out from the edge of the main escarpment of the mountain, while the western half is a low residual embankment which represents the former continuation of the north wall to a junction with the granite outlier above mentioned. The top of this natural embankment is perhaps a hundred feet lower than that of the main northern escarpment.

"The Mojave River now escapes from the basin at the east end of this natural barrier by a deep and narrow canyon in the granite, in which it is proposed to construct a dam for the retention of the water in the reservoir. In my opinion this granite is an excellent site for a dam (Plate IV, Fig. 2), and there are no geological reasons why one should not be constructed here.

"The southern or mountain side of the basin is composed almost exclusively of a granitic rock characterized by large phenocrysts of pink orthoclase feldspar associated with a finer ground mass of plagioclase and biotite, and which may be termed a biotite quartz mononite porphyry in contradistinction from the gray granite in the Victorville hills which is a granodiorite. Like all the granite masses of the desert side whose surfaces are exposed to the weather, this rock is much jointed and broken at the surface by the expansion and contraction due to the diurnal variations of temperature, but the joints will be found closed at slight depths. In general, it may be considered a highly impervious material, well adapted for retaining water when the latter is impounded against it, and also excellent material upon which to construct dams.

"The north escarpment of the basin consists of a steeply sloping cliff of the so-called Hesperia formation, which at one place affords a fresh exposure in a vertical cliff nearly 200 feet in height. Here it is seen to consist of alternating beds of varying thickness of coarse unconsolidated gray angular sands and slightly reddish colored sands containing a very small amount of clay. These beds dip slightly to the north. They are very porous, much more so than is desirable, and the question of leakage through them is a subject which deserves serious consideration before reaching final conclusions as to the availability of this basin for a reservoir site.

"That portion of the northeast barrier of the basin which is composed of the Hesperia formation is the weakest link in the valley wall. It is not only porous like the main north wall, but it is narrow and bordered by lower land on its downstream side. Also I doubt if it will afford a



is about as free from seismic disturbances as any part of southern California."

To obtain some standard for ready comparison a safe section of gravity dam is assumed, all dimensions of which are expressed in terms of the height. The top width is .15h and this continues down for a depth of .20h from whence the section widens in the form of a trapezoid to .65h at the base. The area of cross section thus provided is $.33h^2$. While not the most effective or economical dam it is sufficiently strong and it offers a section for preliminary comparison of one dam with another. Cross sections of the dam sites as shown by Plate VII were taken and as careful examinations as could be made for dams for varying dimensions.

In order to present the results in the form of cost curves rather than yardage curves a cost of $6.00 per cubic yard was assumed for all concrete. The cost of the dams was then computed for heights from 10 to 150 feet and the unit cost was determined for the different capacities. The unit costs for different capacities when plotted give a fairly uniform curve. Fig. 4 shows area, capacity, and cost curves for the reservoirs, area being plotted against depth, capacity against depth, and unit cost against capacity. The unit cost curves are then used to make Fig. 5 in which the several curves represent different combined capacities for the reservoirs and in which the diagrams show the capacity that should be given each reservoir for the most economic combination together with the corresponding unit cost. The curve at the bottom of Fig. 5 is a summary of those above, and shows the unit cost in dollars per acre-foot for the most economic combined capacities in acre-feet. It is found that the most economic combinations within the range of total storage which would be desirable require that the greater part of the capacity be in Reservoir No. 3-A, also that the ratio between the capacities of the two basins is not constant for varying total capacity.

The maximum economic capacity for Reservoir No. 3-A is approximately 35,000 acre-feet which is shown to correspond to the minimum unit cost of $34.50 per acre-foot. Using the same figure as the maximum allowable unit cost for Reservoir No. 2 the maximum economic capacity for this reservoir is 34,000 acre-feet. Again considering the same unit cost as the limit of expense the minimum economic capacity for Reservoir No. 3-A is 28,000 acre-feet and for Reservoir No. 2, 9,400 acre-feet.

Either of these sites is suitable to serve as the reservoir for the first unit in the development of a project and it is gratifying to find such possibilities for economic storage based on such small units. It is in these units that hope for a successful project in Victor Valley must lie

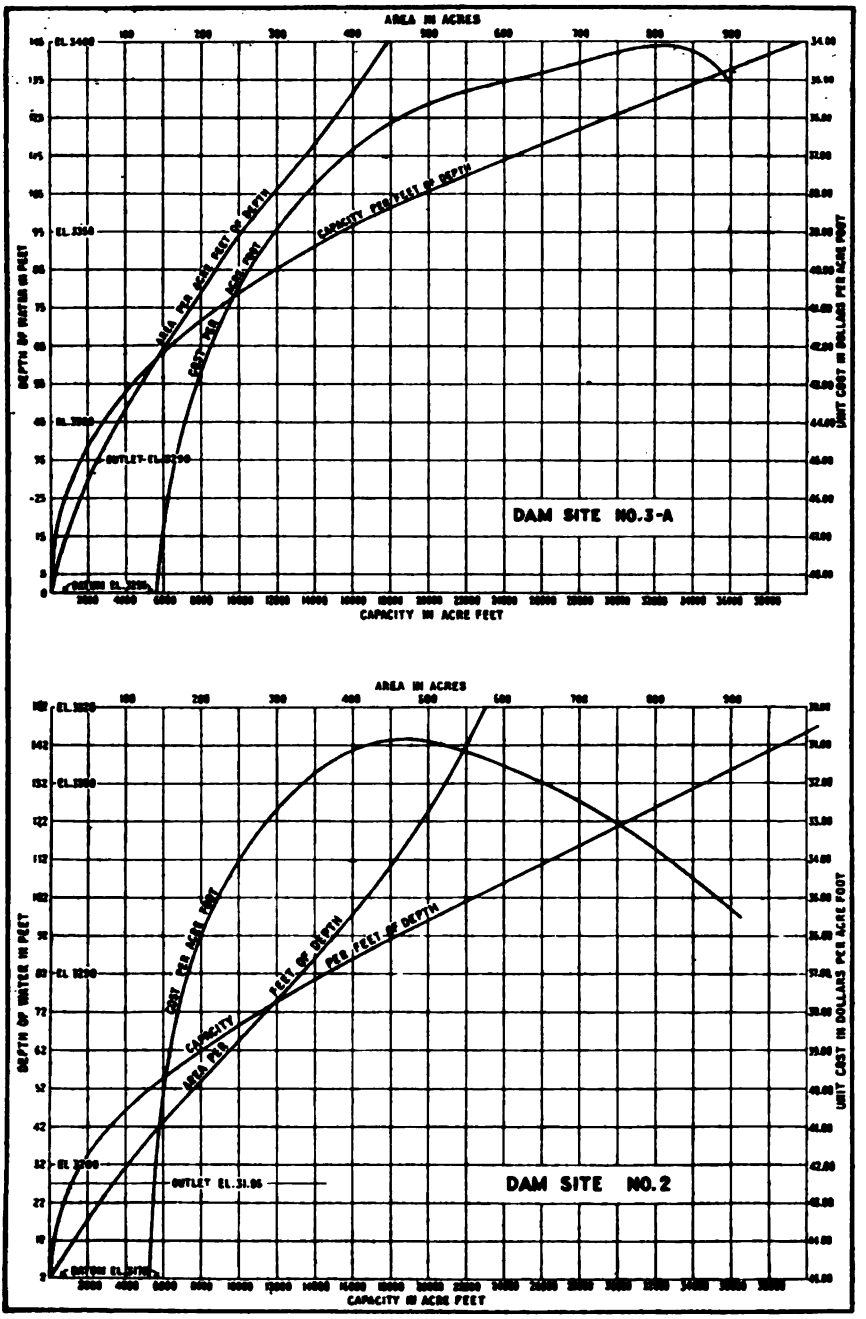

AREA IN ACRES
DEPTH OF WATER IN FEET
UNIT COST IN DOLLARS PER ACRE FOOT
CAPACITY IN ACRE FEET
AREA PER ACRE FOOT OF DEPTH
COST PER ACRE FOOT
CAPACITY PER FEET OF DEPTH
OUTLET EL. 3230
DAM SITE NO. 3-A
AREA IN ACRES
DEPTH OF WATER IN FEET
UNIT COST IN DOLLARS PER ACRE FOOT
CAPACITY IN ACRE FEET
COST PER ACRE FOOT
CAPACITY PER FEET OF DEPTH
AREA PER FEET OF DEPTH
OUTLET EL. 31.95
DAM SITE NO. 2

Fig. 4.—Area, capacity, and cost curves for reservoir sites.

For the complete and most economic utilization of the West Fork waters a much larger storage is needed and a combination of these reservoirs offers the means to this end. The curve, Fig. 5, shows a wide range of capacity to be possible through advantageous combinations of the two reservoirs without much variation in unit cost. For example, by proper combination a total capacity of 60,000 acre-feet can be obtained for approximately $33.25 per acre-foot while a total capacity of only 31,000 acre-feet can be had for $34.00 per acre-foot, with an optimum economic total capacity between these two of 52,000 acre-feet for $32.85 per acre-foot. This indicates a possible flexibility of design which is very desirable and which is seldom obtained.

If the area to be first put under cultivation is too large it may become unwieldy with nonproductive acreage and difficult to carry through the development period while if it be too small the first cost may be too high and the overhead charges proportionately too large. Where a project offers such nearly equal unit cost for varying sizes, the first unit may be conveniently given the most desirable size. In the present case an initial or nucleus project should comprise from 15,000 to 18,000 acres.

With a gross duty of 1.25 acre-feet the water supply required for a district of 16,500 acres, or assuming that 15 per cent of the land is unirrigated, a net area of 14,000 acres is 17,500 acre-feet annually.

The mean annual discharge of the West Fork of Mojave River at the Forks including Grass Valley Creek is about 39,200 acre-feet. The mean annual discharge at the upper dam sites as determined by comparing the measurements at the upper sites with those at the Forks, is about 30,000 acre-feet. It appears from the discharge records that for an annual storage of approximately 30,000 acre-feet, a draft of 60 per cent of the total storage or approximately 18,000 acre-feet per year may safely be made. This is sufficient for a net area of 14,000 acres or allowing for 15 per cent of the district being unirrigated a gross area of 16,500 acres.

If, however, Reservoir No. 3-A only should be used for this initial project some study should be made of the most economic use of this reservoir and of the form of unit development that would be consistent with the full development of the combined reservoirs. Ultimate development would use the full 60,000 acre-feet capacity which should give an annual draft of approximately 30,000 acre-feet or practically the entire average flow of the West Fork.

Fig. 5 shows the economic division of this capacity to be 33,000 acre-feet in Reservoir No. 3-A and 27,000 acre-feet in Reservoir No. 2. Therefore, as a tentative plan it is suggested that Reservoir No. 3-A be constructed to a capacity of 33,000 acre-feet for the first unit. This

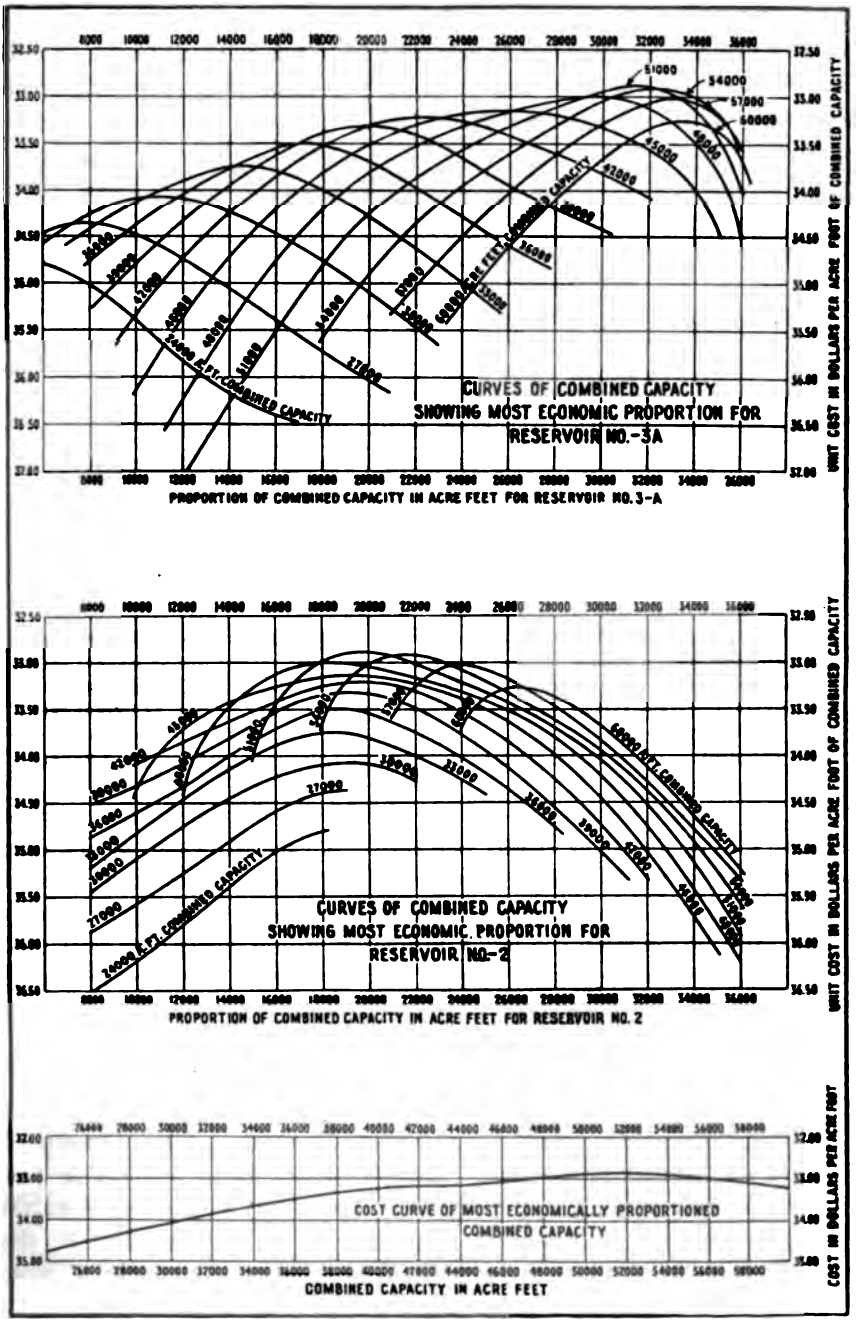

CURVES OF COMBINED CAPACITY
SHOWING MOST ECONOMIC PROPORTION FOR
RESERVOIR NO.-3A
PROPORTION OF COMBINED CAPACITY IN ACRE FEET FOR RESERVOIR NO.3-A
UNIT COST IN DOLLARS PER ACRE FOOT OF COMBINED CAPACITY
CURVES OF COMBINED CAPACITY
SHOWING MOST ECONOMIC PROPORTION FOR
RESERVOIR NO.-2
PROPORTION OF COMBINED CAPACITY IN ACRE FEET FOR RESERVOIR NO. 2
UNIT COST IN DOLLARS PER ACRE FOOT OF COMBINED CAPACITY
COST CURVE OF MOST ECONOMICALLY PROPORTIONED
COMBINED CAPACITY
COMBINED CAPACITY IN ACRE FEET
COST IN DOLLARS PER ACRE FOOT

Fig. 5.—Curves for reservoir sites on West Fork of Mojave River.

should allow a safe annual draft of about 20,000 acre-feet or on the basis of 1.25 acre-feet duty should irrigate a net area of the west mesa of 16,000 acres, or allowing 15 per cent for lands not cultivated, should supply a district of approximately 19,000 acres. The following is an estimate of the cost of such a project:

Dam	$1,125,300 00
Spillway	20,000 00
Land, 400 acres at $100 per acre	40,000 00
Main conduits	198,000 00
Distribution system	322,000 00
Total	$1,705,300 00

The foregoing makes no allowance for interest during construction which would require two years. During the first six months of this period it is probable that the work would be of a preliminary character including the making of the necessary surveys and designs and the acquisition of the lands and water rights pertaining to the project. The cost of this preliminary work is estimated at $100,000. For a tentative scheme of financing therefore it is estimated that interest would be paid on sums as follows:

$100,000 at 5 per cent for 2 years	$10,000 00
500,000 at 5 per cent for 1½ years	37,500 00
600,000 at 5 per cent for 1 year	30,000 00
600,000 at 5 per cent for ½ year	15,000 00
Total	$92,500 00

Adding interest to construction cost gives a total estimated cost of $1,797,800, or a cost of $94.62 per acre. A careful design of the dam should reduce the estimated cost 10 or 15 per cent below the estimate based on the arbitrary section of dam assumed for this preliminary study and comparison. Such a reduction would lower the estimated unit cost of the project to approximately $90.00 per acre including interest.

CONCLUSIONS AND SUGGESTIONS.

No plan for the utilization of Mojave River would be complete without considering the Little Bear Valley Reservoir. The Arrowhead Reservoir and Power Company has invested a large amount in this system for impounding and using the water supply of the upper watershed of the East Fork and is in possession of valuable data on the runoff from the entire watershed. This company controls a large amount of riparian land along the river and has acquired additional appropriation rights. Options on the company's properties are held by the Victor Valley Irrigation District. It is not evident that this

district can be properly supplied with water from Little Bear Valley reservoir at reasonable cost. The length of conduit and the expensive nature of construction required, the limited quantity of water available and the comparatively small amount of power which may be developed point to such a large unit cost as to render the project impracticable. The report of J. B. Lippincott points out that the project is feasible only on the basis of a high duty of water such as one acre-foot and indicates uncertainty as to the sufficiency of this duty. We are of the opinion that a duty of one acre-foot is insufficient for the area included in the district.

We deem it unwise to give special consideration to any particular body of land and hold that the broad problem is not how to deliver the water to some particular lands but how to devise the most economical plan to properly irrigate part of the valley. There is a large area of land but a limited quantity of water.

The flood waters may also be stored at the Victor reservoir site controlled by the Mojave Water and Power Company and although this site is too low to be of service to either of the irrigation districts, plenty of good land on which the water may be used is situated below the site.

In the pursuit of practical means for the utilization of Little Bear Valley Reservoir we suggest that some land of the east mesa may be irrigated with this supply at less expense than may the lands of the west mesa and that such a distribution would also permit the development of more electrical energy. The West Fork reservoir sites may be used to store water for the west mesa lands.

The Appleton Land, Water and Power Company owns extensive lands having riparian rights and some appropriation rights and the pipe lines of this company are in a position to receive the discharge from Little Bear Valley reservoir. For the nucleus of development on the east side and near the river on the west side it would seem that this company's ditch and pipe lines might have a very definite value if used with the Arrowhead Reservoir and Power Company's properties.

The following is a summary of the suggestions and findings.

(1) The proper duty of water is approximately 1.50 acre-feet per acre per annum for the east mesa and 1.25 acre-feet per acre per annum for the west mesa.

(2) The total annual average discharge of Mojave River is approximately 90,000 acre-feet, of which about one-third is available for storage in Little Bear Valley reservoir now partially constructed, about one-third is available for storage in proposed upper West Fork reservoirs, and about one-third should be allowed for the riparian lands along the river.

(8) We suggest the use of the water supply under two projects; one for the west mesa to make use of the upper West Fork reservoirs with an initial unit having storage in Reservoir No. 3-A of 33,000 acre-feet and a district of 18,400 acres and an ultimate project with storage in both reservoirs of 60,000 acre-feet and a district of 29,000 acres; the other to use Little Bear Valley reservoir water from which may be delivered by the shortest route to the lands of the east mesa, utilizing the greater inherent power en route and irrigating approximately 20,000 acres net, or allowing for 15 per cent of the total being unirrigated, a total project area of 23,000 acres. The total net area under the two systems would be about 45,000 acres and allowing 15 per cent for lands unirrigated within the exterior boundaries a total gross area of about 52,000 acres.

APPENDIX

TABLE OF DATA ON WELLS AND PUMPING PLANTS IN VICTOR VALLEY.

Number	Owner	Location			Well						Elevations		Pump			Power	
		Section	Township	Range	Year made	Class	Size, inches	Depth, feet	Depth to water, feet	Date measured	Ground, feet	Water, feet	Kind	Size, inches	Discharge claimed, mi. in.	Kind	Horsepower
1	Martin McInnis	7	S	E	----	Dug	----	22	7.5	Feb. 26, '17	2,945.8	2,938.3	Cylinder	----	----	Windmill	----
2	Martin McInnis	7	S	E	1913	Dug	----	30	10.4	Feb. 26, '17	----	----	Cylinder	----	----	Windmill	----
3	A. Dewitt	7	S	E	----	Dug	----	11	8.3	Feb. 26, '17	2,944.4	2,936.1	None	----	----	None	----
4	— Vlodek	6	S	E	----	Dug	----	20	2.8	Feb. 26, '17	2,931.4	2,928.6	None	----	----	None	----
5	C. F. Hedrick	1	S	E	1916	Drilled	10	216	11.0	Feb. 16, '17	2,935.1	2,924.1	Centrifugal	6	80	Gasoline engine	20
6	F. Spencer	1	S	E	1916	Drilled	12	250	11.0	Feb. 16, '17	2,927.4	2,916.4	Centrifugal	7	100	Gasoline engine	25
7	—— ——	1	S	E	----	Dug	----	----	----	----	2,922.9	----	Cylinder	----	----	Windmill	----
8	M. J. Springer	6	S	E	----	Dug	----	----	5.7	Feb. 26, '17	----	----	None	----	----	None	----
9	Appleton L. W. P. Co	36	4	E	----	Drilled	14	113	3.5	Feb. 17, '17	----	----	None	----	----	None	----
10	Appleton L. W. P. Co	36	4	E	----	Drilled	14	202	----	Feb. 17, '17	----	----	None	----	----	None	----
11	Appleton L. W. P. Co	36	4	E	----	Drilled	14	280	6.2	Feb. 17, '17	2,927.0	2,920.8	None	----	----	None	----
12	I. C. McLaughlin	31	4	E	1905	Drilled	14	34	34.0	Feb. 26, '17	2,910.0	2,876.0	Cylinder	----	----	Windmill	----
13	I. C. McLaughlin	31	4	E	1911	Drilled	8	52	20.9	Feb. 26, '17	2,913.5	2,892.6	Centrifugal	4	52	Gasoline engine	8
14	A. O'Neil	30	4	E	1911	Drilled	12	225	16.4	Feb. 26, '17	2,897.7	2,881.3	Centrifugal	----	140	Gasoline engine	25
15	A. W. Cole	30	4	E	1914	Dug	---	36	31.7	Mar. 6, '17	2,897.7	2,866.0	Cylinder	5x24	7	Gasoline engine	3
16	A. W. Cole	30	4	E	1913	Drilled	12	162	32.8	Mar. 6, '17	2,898.0	2,865.2	Centrifugal	5	80	Gasoline engine	25
17	County Well	19	4	E	----	Dug	---	----	12.6	Mar. 6, '17	2,899.9	2,887.3	None	----	----	None	----
18	G. W. McLester	19	4	E	----	Drilled	10	6	22.7	Feb. 26, '17	----	----	None	----	----	None	----
19	G. W. McLester	19	4	E	----	Drilled	12	----	22.7	Feb. 26, '17	----	----	None	----	----	None	----
20	H. A. Jock	30	4	E	----	Drilled	10	54	18.0	----	2,905.2	2,887.2	Cylinder	8	35	Gasoline engine	6
21	O. A. Minister	29	4	E	----	Dug	----	----	30.0	----	2,896.3	2,866.3	Cylinder	----	9	Gasoline engine	1.5
22	O. A. Minister	29	4	E	1913	Drilled	12	120	24.3	Feb. 25, '17	2,891.2	2,866.9	Centrifugal	6	150	Gasoline engine	22
23	Sidney O'Neil	20	4	E	----	Drilled	12	----	24.5	Feb. 26, '17	2,882.1	2,857.6	None	----	----	None	----
24	J. M. Allison	20	4	E	----	Drilled	10	70	30.0	----	2,880.1	2,850.1	None	----	----	None	----
25	J. M. Allison	20	4	E	----	Drilled	10	70	25.0	----	2,883.4	2,858.4	None	----	----	None	----
26	W. C. Roberts	17	4	E	1915	Drilled	12	155	20.0	----	2,868.5	2,848.5	Centrifugal	6	125	Gasoline engine	20
27	D. W. McPherson	17	4	E	----	Drilled	7	----	20.4	Feb. 25, '17	2,862.4	2,842.0	Cylinder	----	----	Windmill	----
28	D. W. McPherson	17	4	E	1914	Drilled	12	----	20.6	Feb. 25, '17	2,866.8	2,846.2	None	----	----	None	----
29	I. K. Miller	7	4	E	----	Drilled	10	150	19.5	Feb. 25, '17	2,861.9	2,842.4	Centrifugal	8	----	Gasoline engine	----
30	C. G. Lewis	7	4	E	1910	Drilled	12	146	12.0	----	2,854.6	2,842.6	Centrifugal	4	55	Gasoline engine	8
31	H. A. Carden	7	4	E	----	Drilled	10	225	15.1	Feb. 25, '17	2,858.7	2,838.6	Centrifugal	7	----	Gasoline engine	20
32	Harris Garesion	6	4	E	1909	Drilled	12	133	16.0	----	2,842.9	2,826.9	Centrifugal	6	130	Gasoline engine	16

33	E. Garesion	7	4	3	1912	Drilled	12	166	10.0		2,848.8	2,838.8	Centrifugal	7	150	Gasoline engine	25
34	A. H. Hohman	6	4	?		Dug		25	11.8	Feb. 24, '17	2,833.7	2,821.9	Centrifugal	3	24	Gasoline engine	4
35	A. W. Phillips	6	4	3		Drilled	12	94	8.0		2,830.5	2,822.5	Centrifugal	6	216	Gasoline engine	25
36	Orr & Pullar	36	5	4	1909	Drilled	12	110	7.0	Feb. 17, '17	2,825.2	2,818.2	Centrifugal	5	75	Gasoline engine	45
37	Verde Ranch	23	5	4		Drilled	10	260	0.0	April 12, '17	2,751.5	2,751.5	Flowing			None	
38	Verde Ranch	23	5	4		Drilled	10	350	0.0	April 12, '17	2,748.6	2,751.3	Flowing		33	None	
39	Verde Ranch	23	5	4		Drilled	10	92	0.0	April 12, '17	2,750.2	2,751.3	Flowing			None	
40	Verde Ranch	15	5	4		Drilled	10		0.0	April 12, '17	2,765.0	2,776.9	Auxiliary pump			Gasoline engine	
41	Verde Ranch	26	5	4		Drilled	10	552	0.0	April 12, '17	2,782.1	2,783.5	Flowing			None	
42	Verde Ranch	26	5	4		Drilled	10		0.0	April 12, '17	2,782.1	2,783.3	Flowing			None	
43	Verde Ranch	26	5	4		Drilled	10	106	0.0	April 12, '17	2,783.3	2,784.4	Flowing			None	
44	Verde Ranch	26	5	4		Drilled	10		0.0	April 12, '17	2,798.4	2,799.6	Flowing			None	
45	Verde Ranch	26	5	4		Drilled	10		0.0	April 12, '17			Flowing			None	
46	Verde Ranch	35	5	4		Drilled	10		0.0	April 12, '17	2,800.4	2,804.3	Flowing			None	
47	Verde Ranch	35	5	4		Drilled	10	895	0.0	April 12, '17	2,799.1	2,800.4	Flowing			None	
48	Verde Ranch	35	5	4		Drilled	10		0.0	April 12, '17	2,800.2	2,800.7	Flowing			None	
49	Verde Ranch	35	5	4		Drilled	12	270	4.0	April 12, '17	2,811.0	2,807.0	Centrifugal		350	Gasoline engine	60
50	Verde Ranch	35	5	4		Drilled	12	270	4.0	April 12, '17	2,811.0	2,807.0	Centrifugal		350	Gasoline engine	60
51	Verde Ranch	35	5	4		Drilled	12	270	4.0	April 12, '17	2,811.0	2,807.0	Centrifugal		350	Gasoline engine	60
52	Verde Ranch	35	5	4		Drilled	12	306	4.0	April 12, '17			Centrifugal	8		Gasoline engine	25
53	Verde Ranch	36	5	4		Drilled	12	270	12.8	Mar. 5, '17	2,824.0	2,811.2	Centrifugal	12	400	Gasoline engine	60
54	Verde Ranch	36	5	4		Drilled	12	270	12.8	Mar. 5, '17	2,824.0	2,811.2	Centrifugal	12	400	Gasoline engine	60
55	Verde Ranch	36	5	4		Drilled	12	270	12.8	Mar. 5, '17	2,824.0	2,811.2	Centrifugal	12	400	Gasoline engine	60
56	W. and C. H. Shaw	24	5	4		Drilled	14	72	53.0	Feb. 17, '17	2,815.7	2,762.7	Cylinder			Windmill	
57	W. and G. Weldon	24	5	4		Drilled	12	300	50.0		2,801.7	2,751.7	Centrifugal			Gasoline engine	32
58	W. A. Foster	25	5	4	1907	Drilled	10	100	48.0		2,833.0	2,785.0	Centrifugal	6	100	Gasoline engine	25
59	M. L. Foster	19	5	4		Drilled		100	48.0		2,835.0	2,787.0	Double dp. w.		40	Gasoline engine	15
60	E. P. Dewey	31	5	3	1903	Drilled	8	545	23.5	Feb. 24, '17	2,850.0	2,826.5	Centrifugal	6	125	Gasoline engine	
61	Victor Ranch	30	5	3	1905	Drilled	12	500	55.3	Feb. 24, '17	2,845.8	2,799.5	Centrifugal	7	125	Gasoline engine	40
62	W. B. Ames	30	5	3		Drilled	12		47.6	Feb. 24, '17	2,845.8	2,797.2	Centrifugal	7		Gasoline engine	40
63	W. B. Ames	30	5	3		Drilled	12		47.6	Feb. 24, '17	2,848.0	2,800.4	Centrifugal	7		Gasoline engine	32
64	W. C. Smith	31	5	3		Drilled	12						None			None	
65	S. L. Wheatley	31	5	3		Drilled	12		45.3	Feb. 24, '17	2,863.8	2,818.5	Centrifugal			Gasoline engine	25
66	L. C. Bailey	31	5	3		Drilled					2,863.0		Centrifugal			Gasoline engine	18
67	A. W. Phillips	6	4	3		Drilled	10	100	50.0	Feb. 24, '17	2,866.5	2,816.5	Cylinder		6	Gasoline engine	
68	G. L. Smith	6	4	3		Drilled	12	100	50.0		2,878.7	2,828.7	Centrifugal	7		Gasoline engine	40
69	W. A. Westphal	5	4	3	1910	Drilled	12	370	80.0		2,923.4	2,843.4	Centrifugal	6	80	Gasoline engine	40
70	Apple Valley School	5	4	3		Drilled	7	160	100.0		2,923.8	2,823.8	Cylinder			Windmill	
71	Edwin Rhodes	8	4	3	1914	Drilled	14	164	71.0		2,904.1	2,833.1	Turbine	10	100	Gasoline engine	25
72	—— Cozard	7	4	3		Dug		48	46.8	Feb. 25, '17	2,880.4	2,833.6	Cylinder			Windmill	
73	—— Keplinger	8	4	3		Dug			66.0	Feb. 25, '17	2,904.3	2,838.3	Cylinder			Windmill	

TABLE OF DATA ON WELLS AND PUMPING PLANTS IN VICTOR VALLEY—Continued.

Number	Owner	Location			Well						Elevations		Pump			Power	
		Section	Township	Range	Year made	Class	Size, inches	Depth, feet	Depth to water feet	Date measured	Ground, feet	Water, feet	Kind	Size, inches	Discharge claimed, mi. in.	Kind	Horsepower
74	C. F. Ten Eyck	8	4	3	1915	Drilled	14	225	182.0				Turbine	12	45	Gasoline engine	42
75	F. E. Harrison	17	4	3	1912	Dug		81	78.2	Feb. 26, '17			Cylinder			Windmill	
76	N. F. Marsh	20	4	3	1915	Drilled	12	180	100.0		2,969.0	2,869.0	Screw	5	32	Gasoline engine	30
77	W. O. Wade	21	4	3	1916	Drilled	12	650	242.0	Mar. 1, '17	3,090.0	2,848.0	Cylinder			Gasoline engine	2
78	W. C. Harris	8	4	3	1912	Drilled	14	345	186.2	Mar. 1, '17	3,030.9	2,844.7	Single dp. w.	9x30	30	Gasoline engine	30
79	A. E. Hull	9	4	3	1912	Drilled	14	687	188.9	Mar. 1, '17	3,033.9	2,845.0	Centrifugal	5	55	Gasoline engine	60
80	W. M. Hunt, Jr.	10	4	3		Drilled	14	300	212.0	Mar. 1, '17	3,060.4	2,848.4	Double dp. w.	38	42	Gasoline engine	40
81	W. E. Tussing	10	4	3	1917	Drilled	12	385	138.0		3,090.0	2,852.0	Double dp. w.	28	27	Gasoline engine	30
82	R. M. Ferguson	5	4	3	1911	Drilled		272	166.0				None			None	
83	O. L. Morgan	4	4	3	1918	Dug			170.0				Cylinder			Windmill	
84	H. W. Fitzpatrick	4	4	3	1912	Dug			5.0		2,992.9	2,837.9	None			None	
85	J. Billingsley	3	4	3		Dug			149.0	Mar. 3, '17	2,978.9	2,829.9	None			None	
86	O. A. Bonadiman	3	4	3		Drilled		241	190.0		3,030.8	2,840.8	Cylinder			Windmill	
87	T. E. Dennison	2	4	3	1909	Drilled	6	180	159.0		2,997.6	2,838.6	Cylinder			Windmill	
88	J. F. Olsen	2	4	3	1911	Dug		167	159.0		2,995.6	2,836.6	Cylinder			Windmill	
89	W. J. Fifield	2	4	3		Drilled	10		213.0	Mar. 2, '17	3,053.0	2,840.0	Cylinder			Windmill	
90	E. D. S. Pope	1	4	3	1913	Drilled	12	730	196.0		3,037.0	2,841.0	Double dp. w.		10	Gasoline engine	12
91	D. D. Spaid	1	4	3	1914	Drilled	12	250	163.0				Screw	6	30	Gasoline engine	40
92	H. E. Walsh	6	4	2	1914	Drilled	12	340	200.0		3,125.0	2,844.0	Double dp. w.	38	38	Gasoline engine	40
93	A. J. Lintner	6	4	2		Drilled	8		200.0	Mar. 4, '17	3,030.0	2,832.0	None			None	
94	B. Peaks	26	5	3		Dug		150	100.0		2,946.8	2,846.8	Cylinder			Gasoline engine	
95	A. M. Byron	34	5	3	1912	Dug		148	128.5	Feb. 28, '17	2,967.0	2,838.5	Cylinder			Windmill	
96	L. H. Clock	33	5	3	1913	Drilled	12	512	155.2		2,985.2	2,830.0	None			None	
97	C. H. White	5	4	3	1915	Drilled	12	204	166.0		3,002.1	2,836.1	Deep well	6	8	Gasoline engine	7
98	T. J. Anderson	33	5	3		Dug		167	157.4	Feb. 17, '17	2,987.3	2,829.9	None			None	
99	W. Paine	32	5	3		Dug		167	160.0		2,994.5	2,834.5	Cylinder			Windmill	
100	M. F. Ihmsen	32	5	3	1912	Drilled	14	300	164.0		2,994.7	2,830.7	Turbine	12	70	Gasoline engine	60
101	Theresa Smith	32	5	3	1915	Drilled	12	289	151.8	Feb. 27, '17	2,986.8	2,835.0	None			None	
102	A. S. Kibbey	28	5	3	1910	Drilled	10	400	130.0		2,975.9	2,845.9	Turbine	9½	53	Gasoline engine	35
103	K. Evans	29	5	3	1915	Drilled	12	207	155.0		2,968.0	2,813.0	Deep well		15	Gasoline engine	4
104	A. G. Kent	27	5	3	1916	Drilled	12	258	127.0				None			None	
105	W. W. Hitchcock	28	5	3	1912	Drilled	14	492	112.0	May 15, '12	2,951.5	2,839.5	Turbine	8	50	Gasoline engine	40

106	H. C. Decker	22	5	3	1909	Drilled	10	722	107.7	Feb. 28, '17	2,944.7	2,837.0	Air lift			None		
107	N. Elmer	22	5	3		Dug		119	101.9	Mar. 2, '17	2,939.0	2,837.1	None			None		
108	L. L. Lytle	26	5	3		Dug		101	98.3	Mar. 2, '17	2,939.0	2,840.7	None			Gasoline engine		
109	R. D. Sperry	26	5	3		Dug		111	97.8	Mar. 2, '17	2,938.4	2,840.6	None			None		
110	H. Meacham	30	5	2		Drilled	10		109.0	Mar. 3, '17	2,960.0	2,851.0	None			None		
111	—— Rau	24	5	3	1917	Drilled	12	183	87.1	Mar. 2, '17			None			None		
112	—— Harlan	24	5	3		Drilled	12	155	81.8	Mar. 4, '17			Cylinder			None		
113	Verde Ranch	24	5	3		Drilled	12	300	80.0				None			None		
114	N. A. Graffin	14	5	3		Dug		92	80.0	Mar. 3, '17	2,916.0	2,836.0	Cylinder			Gasoline engine		
115	S. Miller	14	5	3		Dug			87.3	Mar. 3, '17	2,926.0	2,838.7	Cylinder			Windmill		
116	E. D. S. Pope	14	5	3	1913	Drilled	12	160	78.3	April 4, '17	2,913.0	2,834.7	None			None		
117	—— Hatch	14	5	3		Dug			Dry		2,906.6		None			None		
118	M. E. Gibson	20	5	3		Dug		138					Cylinder			Windmill		
119	M. W. Minor	20	5	3		Dug		147	Dry				Cylinder			None		
120	A. F. Dennis	18	5	3		Drilled	12	184	125.8	Feb. 27, '17	2,920.4	2,803.6	None			None		
121	—— Cochran	18	5	3		Dug		144	143.0	Feb. 27, '17	2,933.5	2,790.5	Cylinder			Windmill		
122	—— Cochran	18	5	3		Dug		142	138.0	Feb. 27, '17	2,933.5	2,795.5	None			None		
123	J. D. Humiston	18	5	3	1913	Drilled	14	464	97.0	Feb. 27, '17	2,908.0	2,811.0	Deep well		2	None		
124	J. M. Raphael	18	5	3		Dug					2,925.0		None			None		
125	Robert Cook	8	5	3		Dug							Cylinder			Windmill		
126	Robert Cook	8	5	3		Drilled		170	106.0		2,918.0	2,812.0	None			None		
127	Robert Cook	8	5	3		Drilled	10	125	109.2		2,925.0	2,815.8	Cylinder			Gasoline engine		10
128	O. E. Van Horn	22	5	3		Drilled	12	185	107.7	Feb. 28, '17	2,941.5	2,833.8	Cylinder			Windmill		
129	M. M. White	8	5	3		Dug		90	88.0	Mar. 5, '17			Cylinder			Windmill		
130	J. J. Hill	8	5	3		Dug			72.0		2,950.9	2,878.9	None			None		
131	F. A. Fletcher	9	5	3		Drilled		458	89.1	Mar. 5, '17	2,910.0	2,820.9	Centrifugal			Gasoline engine		
132	F. A. Fletcher	9	5	3		Drilled	7	213	77.4	Feb. 28, '17	2,905.5	2,828.1	None		2	None		
133	O. S. Overholt	10	5	3	1902	Dug		85	77.5		2,905.5	2,828.0	Deep well			Gasoline engine		2
134	J. W. Kyle	10	5	3	1915	Drilled	12	218	72.0		2,903.6	2,831.6	Screw		15	Gasoline engine		18
135	J. F. Fitzsimmons	16	5	3		Dug		80	77.6	Mar. 5, '17			None			None		
136	E. D. Mitchell	12	5	3		Drilled			126.0	Mar. 4, '17	2,965.9	2,839.9	None			None		
137	W. H. Bronson	18	5	2		Dug			132.0				None			None		
138	C. M. Abbeys	12	5	3		Dug		127			2,947.3		None			None		
139	M. Liebold	12	5	3		Dug					2,950.9		None			None		
140	E. H. Keller	2	5	3		Dug			116.7	Mar. 4, '17			None			None		
141	J. S. Nation	2	5	3		Drilled	6		108.0				None			None		
142	G. Green	2	5	3		Dug		165	157.6	Mar. 4, '17			Cylinder			Gasoline engine		
143	G. B. Holbrook	4	5	3		Dug		97	72.8	Mar. 5, '17			Cylinder			Windmill		
144	G. B. Holbrook	4	5	3	1909	Drilled	7	94	80.0				Cylinder			Windmill		
145	E. H. Corwin	34	6	3	1910	Dug		110	101.2	Mar. 4, '17			Cylinder			Windmill		
146	Byron Buneman	28	6	3	1915	Drilled	12	193	117.0				Single dp. w.		3	Gasoline engine		18
147	Byron Buneman	28	6	3	1915	Drilled	12	190	120.6	Mar. 4, '17			Screw		6	Gasoline engine		35

TABLE OF DATA ON WELLS AND PUMPING PLANTS IN VICTOR VALLEY—Continued.

Number	Owner	Location			Well						Elevations		Pump			Power	
		Section	Township	Range	Year made	Class	Size, inches	Depth, feet	Depth to water feet	Date measured	Ground, feet	Water, feet	Kind	Size, inches	Discharge claimed, mi. in.	Kind	Horsepower
148	G. A. Ground	7	5	3	1917	Dug	------	133	130.0	----------	----------	----------	None	------	------	None	----
149	A. B. Edmonds	6	5	3	------	Dug	------	------	------	----------	----------	----------	None	------	------	None	----
150	A. B. Sheridan	5	4	2	1915	Drilled	12	311	221.0	----------	3,100.0	2,879.0	None	------	------	None	----
151	John McDonald	8	4	2	1915	Drilled	------	418	255.0	----------	----------	----------	None	------	------	None	----
152	A. L. Martin	5	4	2	------	Drilled	12	280	187.0	----------	3,041.0	2,854.0	Screw	7	60	Gasoline engine	90
153	E. O. Vessey	4	4	2	1915	Drilled	12	450	177.0	Mar. 1, '17	3,027.0	2,850.0	Air lift	------	60	Gasoline engine	60
154	E. Beasley	32	5	2	------	Drilled	12	307	170.0	Mar. 3, '17	3,025.7	2,855.7	None	------	------	None	----
155	J. B. Davis	32	5	2	------	Drilled	10	200	160.7	Mar. 3, '17	3,011.5	2,850.8	Cylinder	------	------	Windmill	----
156	E. R. Wheatley	4	4	2	------	Drilled	7	195	168.0	----------	3,024.9	2,856.9	Cylinder	------	------	Windmill	----
157	E. R. Wheatley	4	4	2	1917	Drilled	------	------	------	----------	3,036.0	----------	None	------	------	None	----
158	D. W. Hurlihy	4	4	2	1915	Drilled	12	500	222.9	Mar. 1, '17	3,075.6	2,852.7	Air lift	------	40	Gasoline engine	----
159	D. W. Hurlihy	10	4	2	1915	Drilled	12	550	220.3	Mar. 1, '17	3,073.2	2,852.9	Air lift	------	40	Gasoline engine	----
160	J. W. Beasley	10	4	2	1915	Drilled	12	501	183.7	Mar. 1, '17	3,058.2	2,874.5	Air lift	------	------	Gasoline engine	----
161	F. Liebold	14	4	2	------	Dug	------	147	144.2	Mar. 2, '17	----------	----------	Cylinder	------	------	Windmill	----
162	W. S. Cherry	12	4	2	------	Drilled	12	270	68.0	----------	----------	----------	Double dp. w.	------	------	Gasoline engine	25
163	W. S. Cherry	12	4	2	------	Drilled	12	70	62.0	----------	----------	----------	Cylinder	------	------	Windmill	----
164	John McPherson	1	4	2	------	Dug	------	24	19.0	----------	----------	----------	Cylinder	------	------	Windmill	----
165	—— Lockhart	6	4	1	------	Dug	------	------	------	----------	----------	----------	None	------	------	None	----
166	—— Lockhart	6	4	1	------	Dug	------	30	24.3	Mar. 2, '17	----------	----------	Centrifugal	------	------	Gasoline engine	----
167	—— Lockhart	6	4	1	------	Dug	------	30	26.4	Mar. 2, '17	----------	----------	Cylinder	------	------	Windmill	----
168	C. P. Summers	5	4	1	------	Dug	------	26	23.4	Mar. 2, '17	----------	----------	Cylinder	------	------	Windmill	----
169	C. P. Summers	5	4	1	------	Dug	------	26	23.4	Mar. 2, '17	----------	----------	Cylinder	------	------	Windmill	----
170	F. H. Hunt	35	4	5	1913	Drilled	12	816	750.0	----------	3,613.9	2,863.9	Cylinder	------	------	None	----
171	S. Zaesek	15	4	6	1912	Drilled	12	909	869.5	----------	3,809.0	2,939.5	Cylinder	3x4	1	Gasoline engine	14
172	L. J. Hampton	23	4	5	1914	Drilled	12	802	650.0	----------	3,551.9	2,901.9	Deep well	5	5	Gasoline engine	15
173	F. W. Lang	35	5	6	------	Drilled	12	598	505.3	April 6, '17	3,405.9	2,900.6	None	------	------	None	----
174	Verde Ranch	5	4	5	------	Drilled	12	644	510.0	April 11, '18	3,390.0	2,880.0	None	------	------	None	----
175	F. C. Lang	22	5	6	1914	Drilled	12	536	330.0	----------	3,254.5	2,924.5	Double dp. w.	7	33	Gasoline engine	40
176	Julia Lang	22	5	6	------	Drilled	12	475	328.5	April 6, '17	3,250.1	2,921.6	None	------	------	None	----
177	Secord & Black	12	4	5	1914	Drilled	12	572	490.0	April 12, '18	3,351.5	2,861.5	Cylinder	------	------	None	----
178	Appleton L. W. & P. Co.	21	5	4	------	Drilled	8	788	342.9	----------	3,200.0	2,859.0	None	------	------	None	----
179	W. W. Yeager	18	5	5	1915	Dug	------	305	296.6	April 6, '17	3,142.8	2,844.2	None	------	------	None	----

180	O. R. Smyth	15	5	5	1902	Drilled	8	323	292.5	April 6, '17	3,000.3	2,817.8	Cylinder			Windmill	
181	S. V. Benson	20	5	5	------	Drilled	7	365	328.0	Mar. 8, '17	3,165.3	2,842.3	None			None	
182	Appleton L. W. & P. Co.	16	5	4	------	Drilled	14	361	29.0	Feb. 24, '17	2,848.3	2,819.3	Turbine		35	Gasoline engine	
183	W. G. Dobie	22	5	5	1912	Drilled	10	340	306.0	------	3,125.9	2,820.9	Double dp. w.	5x18		None	
184	W. G. Dobie	22	5	5	1903	Drilled	5	325	300.0	------	3,125.9	2,825.9	Single dp. w.	3½x4x8		Gasoline engine	
185	H. T. Woods	22	5	5	1908	Drilled	8	340	297.5	------	3,121.0	2,823.5	Double dp. w.	5x30	12	Gasoline engine	
186	P. S. Carl	12	5	5	1909	Dug	------	------	148.1	Mar. 8, '17	2,938.3	2,794.2	None			None	
187	A. M. Corder	12	5	5	------	Drilled	8	80	70.0	------	------	------	None			None	
188	A. T. & S. F. R. R.	13	5	5	------	Drilled	8	300	70.0	------	2,987.1	2,897.1	None			None	
189	O. H. Smith	2	5	5	1909	Dug	------	156	153.0	------	2,949.6	2,796.6	Cylinder			Windmill	
190	O. H. Smith	2	5	5	1913	Dug	------	------	120.9	Mar. 8, '17	2,902.2	2,781.3	None			None	
191	E. L. De Bolt	8	5	5	1912	Drilled	12	285	238.6	Mar. 8, '17	3,050.0	2,811.4	Deep well			Gasoline engine	12
192	L.W. De Bolt	12	5	6	1913	Dug	------	------	211.0	April 6, '17	3,065.0	2,854.0	Cylinder			Windmill	
193	J. D. Caldwell	6	5	5	1912	Drilled	10	650	174.6	Mar. 8, '17	------	------	Deep well		25	Gasoline engine	16
194	J. Biscar	32	6	5	1912	Drilled	12	243	112.0	------	------	------	Double dp. w.	18	20	Gasoline engine	15
195	E. S. Fisk	34	6	5	------	Dug	------	------	150.0	Feb. 18, '18	2,925.0	2,775.0	Cylinder		3	Gasoline engine	
196	J. M. Scott	34	6	5	------	Drilled	------	157	137.0	------	------	------	Cylinder	3		Gasoline engine	1
197	H. Martin	33	6	5	------	Drilled	------	------	------	------	------	------	Cylinder	5		Gasoline engine	
198	J. L. Trummond	26	6	5	------	Drilled	6	500	153.2	April 5, '17	------	------	None			None	
199	H. K. Hedges	14	6	5	------	Dug	------	------	119.0	Feb. 13, '18	2,841.1	2,722.1	Cylinder	5		None	
200	H. K. Hedges	14	6	5	------	Dug	------	------	120.0	Feb. 13, '18	2,836.7	2,716.7	None			None	
201	E. K. Isaacs	16	6	5	------	Drilled	12	158	102.0	Feb. 13, '18	2,838.3	2,736.3	Cylinder	5x20	12	Gasoline engine	15
202	E. H. Richardson	28	6	5	------	Drilled	12	595	113.0	Feb. 13, '18	2,879.5	2,766.5	Air lift	7½x12	40	Gasoline engine	80
203	E. H. Richardson	28	6	5	1916	Drilled	14	------	124.3	April 5, '17	------	------	Air lift	7½x12	40	Gasoline engine	80
204	E. H. Richardson	20	6	5	------	Drilled	12	------	88.0	Feb. 14, '18	2,857.6	2,769.6	Cylinder			Windmill	
205	E. H. Richardson	20	6	5	------	Drilled	12	------	89.0	Feb. 14, '18	2,857.0	2,768.0	None			None	
206	E. H. Richardson	20	6	5	------	Drilled	------	------	------	------	------	------	None			None	
207	W. S. Lehman	27	6	5	------	Drilled	7	709	100.0	------	------	------	None			None	
208	—— Campbell	8	6	5	------	Drilled	------	295	------	------	------	------	None			None	
209	A. M. Steele	5	5	7	------	Drilled	6	390	282.0	------	3,155.1	2,923.1	Cylinder			Gasoline engine	
210	O. W. Jessup	9	5	7	------	Drilled	8	350	290.0	------	3,211.1	2,931.1	Cylinder			Gasoline engine	3
211	T. O. Ford	4	5	7	------	Drilled	12	300	238.3	April 7, '17	3,157.4	2,919.1	Cylinder	4		Gasoline engine	6
212	G. S. Pownald	2	5	7	1913	Drilled	6	380	235.0	------	3,157.8	2,922.8	Cylinder			Windmill	
213	De Meville-Rowley	12	5	7	------	Drilled	12	415	315.0	------	------	------	None			None	
214	W. Sly	6	5	6	1911	Drilled	12	------	251.0	Feb. 19, '18	3,149.3	2,898.3	None			None	
215	G. W. Phenice	31	6	7	1915	Drilled	12	410	153.4	April 7, '17	------	------	None			None	
216	Paul Showers	30	6	7	1915	Drilled	12	295	80.0	------	------	------	Deep well			Gasoline engine	1½
217	H. M. Engebritson	27	6	7	1915	Dug	------	150	135.0	------	------	------	Deep well		1	Gasoline engine	3
218	W. Campbell	27	6	7	1916	Drilled	12	400	125.0	------	------	------	Centrifugal	3	25	Gasoline engine	6
219	C. B. Hawks	21	6	7	------	Dug	------	97	------	------	------	------	Deep well		1	Gasoline engine	3
220	J. R. Palmer	22	6	7	1912	Drilled	12	330	78.0	------	------	------	None			None	
221	C. Williams	22	6	7	------	Drilled	12	425	73.0	April 6, '17	------	------	Air lift		18	Gasoline engine	35

TABLE OF DATA ON WELLS AND PUMPING PLANTS IN VICTOR VALLEY—Continued.

Number	Owner	Location			Well					Elevations		Pump			Power	
		Section	Township	Range	Year made	Class	Size, inches	Depth, feet	Depth to water, feet	Date measured	Ground, feet	Water, feet	Kind	Size, inches	Discharge claimed, mi. in.	Kind	Horsepower
222	D. Anderson	24	6	7	-----	Dug	-----	61	57.0	Feb. 21, '18	2,922.0	2,865.0	None	-----	-----	None	----
223	H. Braden	24	6	7	-----	Drilled	-----	-----	88.6	Mar. 7, '17	-----	-----	None	-----	-----	None	----
224	C. H. Sampson	30	6	6	1915	Drilled	12	250	133.2	Mar. 7, '17	-----	-----	None	-----	-----	None	----
225	C. H. Sampson	30	6	6	1911	Drilled	12	136	133.2	Mar. 7, '17	-----	-----	None	-----	-----	None	----
226	F. Reinke	32	6	6	1910	Drilled	12	380	131.0	Feb. 20, '18	3,047.8	2,916.8	None	-----	-----	None	----
227	J. W. Walker	28	6	6	-----	Drilled	12	136	102.0	-----	2,948.3	2,846.3	Cylinder	-----	-----	Gasoline engine	----
228	L. M. Cotton	28	6	6	1915	Drilled	12	150	105.0	Feb. 20, '18	2,948.9	2,843.9	Deep well	-----	-----	Gasoline engine	3
229	W. B. Phillips	18	6	6	1911	Drilled	12	76	45.0	-----	-----	-----	None	-----	-----	None	----
230	F. P. Williams	18	6	6	-----	Drilled	12	-----	48.9	April 7, '17	-----	-----	None	-----	-----	None	----
231	F. P. Williams	18	6	6	-----	Drilled	12	205	32.0	-----	-----	-----	Deep well	-----	-----	Gasoline engine	4
232	R. Atz	14	6	7	1912	Dug	-----	-----	-----	-----	-----	-----	Cylinder	-----	-----	Gasoline engine	3
233	Ed White	15	6	7	-----	Drilled	8	58	49.0	-----	-----	-----	Deep well	-----	-----	Gasoline engine	3
234	W. Huston	20	6	7	-----	Dug	-----	67	65.3	April 7, '17	-----	-----	None	-----	-----	None	----
235	Etta McKelvey	17	6	7	1916	Drilled	12	300	73.5	April 7, '17	-----	-----	None	-----	-----	None	----
236	W. J. Shaw	18	6	7	-----	Dug	-----	-----	55.5	Feb. 17, '18	2,920.8	2,865.3	None	-----	-----	None	----
237	E. Bonino	18	6	7	-----	Dug	-----	-----	50.0	Feb. 17, '18	2,897.8	2,847.8	None	-----	-----	None	----
238	W. E. Anderson	18	6	7	-----	Dug	-----	-----	52.0	-----	-----	-----	None	-----	-----	None	----
239	F. A. Forsyth	7	6	7	1914	Drilled	8	50	37.5	Feb. 16, '18	2,870.4	2,832.9	None	-----	-----	None	----
240	J. Dobersch	7	6	7	-----	Drilled	12	-----	-----	-----	-----	-----	None	-----	-----	None	----
241	G. B. Flock	8	6	7	-----	Drilled	8	42	37.0	-----	-----	-----	None	-----	-----	None	----
242	I. S. Lindley	9	6	7	1914	Drilled	8	-----	-----	-----	-----	-----	None	-----	-----	None	----
243	E. F. Anger	10	6	7	-----	Dug	-----	140	24.0	-----	2,857.1	2,818.1	Cylinder	-----	-----	Gasoline engine	----
244	J. Seward	11	6	7	-----	Dug	-----	-----	23.2	-----	2,869.0	2,845.8	Deep well	-----	-----	Gasoline engine	----
245	E. J. Krause	11	6	7	1916	Drilled	12	210	21.0	Feb. 21, '18	2,849.2	2,828.2	Centrifugal	-----	42	Gasoline engine	8
246	K. McDonald	11	6	7	-----	Dug	-----	25	21.5	Feb. 21, '18	2,853.9	2,832.4	None	-----	-----	None	----
247	Grace E. Davis	2	6	7	1916	Drilled	14	226	20.5	Feb. 21, '18	2,841.1	2,820.6	Centrifugal	5	45	Gasoline engine	15
248	W. M. Gray	3	6	7	1912	Drilled	12	302	16.0	-----	-----	-----	None	-----	-----	None	----
249	W. M. Gray	3	6	7	-----	Drilled	12	367	23.1	Mar. 7, '17	-----	-----	None	-----	-----	None	----
250	T. R. Croswell	4	6	7	1912	Drilled	12	183	27.0	-----	-----	-----	Deep well	-----	15	Gasoline engine	15
251	T. R. Croswell	9	6	7	-----	Dug	-----	26	26.0	-----	-----	-----	None	-----	-----	None	----
252	Marian B. Charles	5	6	7	1912	Drilled	7	157	25.0	-----	-----	-----	Centrifugal	2½	18	Gasoline engine	15
253	Marian B. Charles	5	6	7	1917	Dug	-----	41	36.0	Feb. 16, '18	2,853.3	2,817.3	Cylinder	6x8	4	Gasoline engine	6

254	W. H. Anderson	5	6	7	1916	Drilled	8	58	22.0				Centrifugal	½	15	Gasoline engine	10
255	S. P. R. R.	7	6	6	1890	Dug		24	23.0	Feb. 14, '18	2,838.2	2,815.2	None			None	
256	L. O. Wheeler	35	7	7		Dug			42.0	Feb. 14, '18	2,859.3	2,717.3	Centrifugal			Gasoline engine	5
257	C. W. Broekman	32	7	7	1915	Drilled	12	80	27.0	Feb. 16, '18	2,843.3	2,816.3	None			None	
258	L. L. Whitlock	28	7	7		Drilled	7	93	31.0	Feb. 16, '18	2,848.0	2,817.0	Centrifugal	4		Gasoline engine	15
259	C. Munsey	22	7	7	1913	Drilled	7	118	78.0				Cylinder			Windmill	
260	L. Hess	27	7	7	1917	Drilled	10	125	46.0	Feb. 16, '18	2,862.9	2,816.9	Centrifugal	6	75	Gasoline engine	
261	J. Young	8	7	7		Dug		100	95.0				None			None	
262	F. Busch	10	5	4	1917	Dug			8.0		2,719.6	2,711.6	Centrifugal	3		Gasoline engine	6
263	G. Smith	10	5	4		Drilled	14	59	3.0		2,714.0	2,711.0	Centrifugal	6		Electric	10
264	E. Doulch	10	5	4		Drilled	14	39	10.5		2,715.8	2,705.3	None			None	
265	S. Rogers	3	5	4		Drilled			14.6		2,708.6	2,694.0	Cylinder			Windmill	
266	C. Bassini	34	6	4		Drilled	14	75			2,696.4		Centrifugal	4	70	Gasoline engine	18
267	C. Bassini	34	6	4		Drilled	12	107	87.0		2,758.4	2,671.4	Deep well	5x18	30	Gasoline engine	5
268	—— Hadley	34	6	4		Drilled			56.3	Feb. 16, '17			None			None	
269	—— ——	10	5	4		Dug			48.2		2,770.9	2,722.7	None			None	
270	—— ——	5	5	5		Dug					2,780.7		None			None	
271	—— ——	32	6	4		Dug			3.0		2,737.3	2,734.3	None			None	
272	—— ——	32	6	4		Dug			9.1		2,721.4	2,712.3	None			None	
273	Victor Cement Co.	18	6	4	1909	Drilled	12	260					Centrifugal	3		Electric	15
274	Victor Cement Co.	18	6	4	1916	Drilled	16	125					Centrifugal	8	180	Electric	30
275	Victor Cement Co.	18	6	4	1916	Drilled	16	270					Centrifugal	8	180	Electric	30
276	W. Watkins	30	7	4	1914	Drilled	12	202	54.0				Double dp. w.	8	15	Gasoline engine	12
277	W. Watkins	30	7	4	1914	Drilled	12	100	15.0				Centrifugal	4		Gasoline engine	16
278	C. A. Poole	19	7	4	1916	Drilled	12	225	30.6	April 8, '17			Centrifugal	8	12	Gasoline engine	32
279	A. Edwards	26	7	5		Dug			171.0	Feb. 18, '18	2,737.0	2,566.0	None			None	
280	J. M. Peden	27	7	5		Dug							None			None	
281	—— Kirkpatrick	27	7	5		Dug							None			None	
282	W. Warren	27	7	5		Dug			81.0	Feb. 18, '17	2,715.3	2,637.3	None			None	
283	—— Gwyne	15	7	5		Drilled	12	235					None			None	
284	Y. M. C. A.	31	7	5	1914	Drilled	12	230					None			None	
285	—— Mallman	2	6	5	1915	Drilled	12	235	208.0	Feb. 18, '18	2,786.0	2,578.0	None			None	
286	L. P. Burgmeir	26	7	5		Dug			105.0	Feb. 18, '18	2,724.0	2,619.0	None			None	
287	—— ——	2	6	5		Dug			204.0	Feb. 18, '18	2,780.0	2,576.0	Cylinder			Windmill	
288	—— ——	10	6	5		Dug			108.0	Feb. 18, '18	2,807.0	2,699.0	None			None	
289	E. H. Richardson	28	6	5	1917	Drilled	12				2,878.0		None			None	
290	E. H. Richardson	28	6	5	1917	Drilled	8	350	133.0	Feb. 14, '18	2,878.0	2,745.0	None			None	
291	—— ——	14	6	5		Dug			113.5	Feb. 18, '18	2,823.0	2,709.5	None			None	
292	B. S. Hook	14	6	6		Dug			42.5	Feb. 20, '18	2,833.0	2,790.8	Centrifugal			Gasoline engine	
293	W. J. Jensen	35	7	7		Drilled	12	203	36.0	Feb. 14, '18	2,853.0	2,817.0	None			None	
294	B. M. Elsey	26	7	7		Dug		44	42.0	Feb. 14, '18	2,857.0	2,815.0	None			Gasoline engine	

TABLE OF DATA ON WELLS AND PUMPING PLANTS IN VICTOR VALLEY—Continued.

Number	Owner	Location			Well					Elevations		Pump			Power	
		Section.	Township.	Range.	Year made.	Class.	Size, inches.	Depth, feet.	Depth to water, feet.	Date measured	Ground, feet.	Water, feet.	Kind	Size, inches.	Discharge claimed, mi. in.	Kind	Horsepower
295	—— Gilbert	26	7	7	1917	Dug	------	------	74.0	Feb. 14, '18	2,891.0	2,817.0	None	------	------	None	----
296	L. B. Coleman	6	5	7	------	Drilled	10	------	199.0	Feb. 17, '18	3,109.0	2,910.0	None	------	------	None	----
297	John Breen	35	7	7	------	Dug	------	25	20.0	Feb. 21, '18	2,837.5	2,817.5	None	------	------	None	----
298	—— ——	2	6	7	------	Dug	------	------	17.0	Feb. 21, '18	2,835.7	2,817.7	None	------	------	None	----
299	El Mirage School	3	6	7	------	Dug	------	------	22.0	Feb. 21, '18	2,842.8	2,820.8	None	------	------	None	----
300	—— ——	12	6	7	------	Dug	------	------	21.0	Feb. 21, '18	2,867.0	2,846.0	Cylinder	------	------	Windmill	----
301	F. L. Thomas	18	4	5	------	Drilled	7	330	Dry	------	------	------	None	------	------	None	----
302	W. H. Robinson	6	6	4	------	Dug	------	41	35.0	------	------	------	Cylinder	------	------	Windmill	----
303	E. B. Rowley	19	7	4	------	Drilled	------	270	60.0	------	------	------	Centrifugal	------	100	Gasoline engine	60
304	E. B. Rowley	19	7	4	------	Dug	------	110	92.0	------	------	------	None	------	------	None	----
305	P. Herlick	7	7	4	------	Dug	------	40	34.0	------	------	------	None	------	------	None	----
306	F. C. Abbott	18	7	4	------	Drilled	------	270	55.0	------	------	------	Centrifugal	------	105	Gasoline engine	40
307	C. A. Garbutt	21	6	5	------	Dug	------	------	170.0	------	------	------	None	------	------	None	----
308	A. H. Diamond	26	6	5	------	Dug	------	------	120.0	------	------	------	None	------	------	None	----
309	H. C. Jones	19	6	5	------	Dug	------	87	75.0	------	------	------	None	------	------	None	----
310	J. C. White	30	6	5	------	Dug	------	------	96.0	------	------	------	None	------	------	None	----
311	Olive A. Stone	30	6	5	------	Dug	------	------	100.0	------	------	------	None	------	------	None	----
312	W. L. Norris	20	6	6	------	Drilled	12	------	130.0	------	------	------	None	------	------	None	----
313	—— ——	27	6	6	------	Drilled	12	------	128.0	------	------	------	None	------	------	None	----
314	R. R. Jamison	18	6	6	------	Dug	------	58	56.0	------	------	------	None	------	------	None	----
315	R. R. Jamison	14	6	6	------	Dug	------	50	43.0	------	------	------	None	------	------	None	----
316	—— ——	14	6	6	------	Dug	------	54	40.0	------	------	------	Cylinder	------	------	Windmill	----
317	W. W. McKinney	30	6	7	------	Dug	------	159	139.0	------	------	------	None	------	------	None	----
318	G. Penaul	2	5	6	------	Dug	------	------	236.0	------	------	------	None	------	------	None	----
319	T. A. De Bolt	12	5	6	------	Dug	------	------	150.0	------	------	------	None	------	------	None	----
320	D. S. Ball	12	5	6	------	Drilled	------	423	300.0	------	------	------	None	------	------	None	----
321	P. Welle	18	5	5	------	Drilled	------	365	313.0	------	------	------	None	------	------	None	----
322	S. I. Pickert	34	5	5	------	Drilled	------	578	570.0	------	------	------	None	------	------	None	----
323	—— ——	24	5	5	------	Drilled	------	------	240.0	------	------	------	None	------	------	None	----
324	—— ——	1	5	5	------	Dug	------	------	119.0	------	------	------	None	------	------	None	----
325	A. T. & S. F. R. R.	10	5	4	------	Drilled	------	200	10.0	------	------	------	Centrifugal	------	------	Electric	----

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